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School aged children: Visual perception and reversal recognition of letters and numbers separately and in context

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SCHOOL AGED CHILDREN: VISUAL PERCEPTION AND REVERSAL RECOGNITION OF LETTERS AND NUMBERS SEPARATELY AND IN CONTEXT

By

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USE OF THESIS

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ABSTRACT

Visual discrimination, spatial orientation, and recognition of letters and numbers in context are important issues in helping young students achieve good literacy and numeracy standards. Thus, measures of Visual Discrimination of Upper Case Letters (VDUCL), Visual Discrimination of Lower Case Letters (VDLCL), and Visual Discrimination of Numbers (VDN) as well as Spatial Orientation of Letter and Number Pairs (SOLNP), Form Constancy of Letters and Numbers (FCLNP), Letter and Number Sequencing (LNS), Figure Ground of Letters in Words FGLW) and Figure Ground Numbers in Calculations (FGNC) must be linear and uni-dimensional so that student weaknesses can be identified objectively. The Simple Logistic Model of Rasch Measurement was used to order the items on a scale from easy to difficult and the student measures were calibrated on the same scale from low to high. In each scale, items were scored zero (for incorrect) and one (for correct).

The student sample N=324 used in this study included pre-primary and primary students in Perth, Western Australia. The initial data were adjusted so that items which displayed misfit statistics were removed from each scale prior to final analysis. The final VDUCL scale (18 items), VDLCL scale (31 items), and VDN scale (14 items) each had a good fit to the measurement model, and were internally reliable. In each scale, there was good agreement about the item difficulties from easy to hard along the scale. Item discrimination and targeting was good. The scales allow teachers to objectively identify the letters and numbers that students find difficult to discriminate and those students who have poor visual discrimination skills of alphabet letters and numbers so that tailored teaching can be applied to those in need.

The final SOLNP scale (27 items) had a reasonable fit while the final LNS scale (36 items), FCLN scale (24 items), FGLW scale (34 items), and FGNC scale (15 items) all had a good fit to the measurement model. These five scales were internally reliable, displayed reasonable agreement about the item difficulties and item discrimination and targeting was good. The scales allow teachers to objectively identify the spatial aspects of letters and numbers that students find difficult to identify as well as the letters and numbers that students find difficult to identify in different fonts and in context. In addition, those students who have poor visual spatial orientation, sequencing skills poor visual form constancy and figure ground skills of letters and numbers are objectively identified so that tailored teaching can be applied to those in need.

Valid inferences about students' abilities to discriminate numbers and letters separately, in context and with reversals were drawn from the linear student measures on the eight scales. The main inferences indicate that students with the lowest scores were those who had most difficulty recognising reversed letters and numbers when presented individually, in sequences, in a variety of fonts, in words or calculations. Students found it easiest to discriminate individual letters and numbers, in contrast to those that appear in the context of words, sequences and calculations. The ratio of boys to girls in the lowest student measures was relatively even. As was expected, the poorest student measures occur at the younger ages and grades.

DEDICATION

THIS WORK IS DEDICATED TO MY FAMILY WHO WALKED THE DOCTORAL PATH WITH ME IN PATIENT SUPPORT,

AND TO ALL THE CHILDREN WHOSE FRUSTRATIONS ARE EXPRESSED IN THE ANONYMOUS POEM BELOW

Brayns

Im mils mor clewer than enniwun els

Thers millions of brayns in mi hed,

I can mayk modls that reelly work

And big kyts to fli overhed.

My pictures ar beter than orl the rest,

But I ownli got two in the speling test.

ANON

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I cannot fail to acknowledge the extreme sacrifices made by my family during the research journey in order to provide me with the most productive environment to produce the thesis. They have sacrificed time, space and exercised patience in this long passage through my frustrations, ups and downs during the completion of this thesis.

Janet Richmond
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CHAPTER ONE

INTRODUCTION

Background to the Problem

Visual perception is required for the successful performance of most activities of daily living. Such activities as dressing, making a cup of tea, driving a car and reading require visual perceptual skills of body scheme, spatial relations, figure-ground, depth perception, left/right discrimination and line orientation (Cooke, McKenna, Fleming, & Darnel, 2006b). Individuals presenting with visual perceptual dysfunction relating to letters and numbers require visual perceptual assessment to provide a baseline and reference point for appropriate intervention that in turn will facilitate a return to an optimum level of independence when performing valued occupational roles (such as being a student, leisure participant or worker). Assessment of visual perception measures change over time and documents rehabilitation outcomes (Cooke et al., 2006b). High quality visual perceptual tests are essential for this to occur.

The Problem Related to Education in Western Australia

A National Literacy and Numeracy Plan was initially endorsed by State, Territory and Commonwealth Ministers in Australia in 1999 to improve literacy and numeracy standards in the Australia. Some key standards agreed upon were that all students should be assessed by the teacher at an early stage of their schooling in order to address the literacy and numeracy needs of students at risk, and intervention should be implemented as early as possible for students identified as at risk (Australian Council for Educational Research, 1999). To identify students at risk, the National Assessment Program Literacy and Numeracy (NAPLAN) (Department of Education and Training, 2008) has been instituted to assess children in Year Three, Five and Seven, however this does not fit with early identification of students as stated by the Australian Council for Educational Research. In addition, the final report of literacy and numeracy review in Western Australia found that there was a need for pre-primary diagnostic assessment of pre-reading and numeracy skills to identify the students at risk (Department of Education and Training, 2007), while the Western Australian Government has developed a plan to improve the literacy and numeracy outcomes of students in Western Australia (Government of Western Australia, 2007). These policies and plans require relevant, linear, user friendly assessments to identify students at risk so that the plans to improve literacy and numeracy skills at the earliest opportunity can be implemented.

The Problem Related to Occupational Therapy

Paediatric occupational therapists are increasingly making use of standardised tests to determine eligibility for therapy services, monitor progress, and plan appropriate treatments (Canadian Association of Occupational Therapists, 2004; Martin, 2006; Richardson, 1996). Standardised tests allow for the precise measurement of the child's performance in a specific skill area according to the 'norm' or average for a particular age level. However, standardised tests are limited by their psychometric properties and evidence of validity to assess a given construct, such as letter and number recognition in a given population. Standardised tests must be linear, valid and reliable in order to facilitate accurate assessment, therapy and progress measurement. Tests of visual perceptual skills therefore need to have strong properties of measurement like evidence of reliability and validity.

Many children diagnosed with learning disabilities, developmental delays, and neurological impairment present with visual perceptual dysfunction related to letter and number reversal recognition. The current tests that exist to evaluate letter and number reversal recognition skills (such as the *Jordan Left-Right Reversal Test* and the *Test of Pictures / Forms / Letters / Numbers / Spatial Orientation & Sequencing Skills*) are dated, non-linear and exhibit poor levels of reliability and validity (Burns & Snow, 2006; Cotter, Rouse, & DeLand, 1987). In addition, these tests were developed in the United States of America, and Australian norms have not been established. Therefore, a new test of this type developed within a combined visual perceptual and occupational performance framework is urgently needed for Australian paediatric occupational therapists and teachers. Such an instrument would be a valuable asset for therapists who work with school-age children in their clinical practice.

The development and initial validation of a test that evaluates the visual perceptual letter and number reversal recognition skills of school-age children in this project involves ensuring that the test will meet the criteria of assessing visual perceptual constructs using letters and numbers, while remaining within an occupational performance framework. The test framework will be informed by existing models and theoretical frameworks as elaborated below.

Perceptual Assessment in Occupational Therapy

Research literature indicates that there is a need for a test of school-age children's visual perceptual skills related to the recognition of reversal of letters, numbers and letter order that is relevant to occupational performance (Jordan, 1990; Schneck, 2005). The current letter/number reversal tests used by occupational therapists are dated, have limited reliability and validity, are not linear and are not Australian based. Hence, there is a need to develop a new visual perceptual letter/number reversal recognition test that is psychometrically sound (accurate, reliable, valid, and exhibit clinical utility). Since academic achievement (writing, spelling, and reading) as well as various self-care tasks (such as dressing, following a recipe, meal preparation and using a computer) are products of a child's daily occupational performance, it often falls within the occupational therapy realm to assess and intervene in these areas of difficulty.

The framework of occupational performance within which a visual perceptual reversal recognition test can be used was formulated using the models and theoretical frameworks expounded in the *Canadian Model of Occupational Performance* (Canadian Association of Occupational Therapists, 2004)*, The International Classification of Functioning, Disability and Health (ICF)* (World Health Organization, 2003), as well as current visual perceptual and visual motor theories from research literature (Cratty, 1979; Kramer & Hinojosa, 1999; Melamed, 2000; Penso, 1992).

Statement of Purpose

The aims of this study are to:

1. Formulate a conceptual model of visual perceptual integration relevant to the identification of letters and numbers.

2. Create linear, uni-dimensional measures of letter and number recognition related to visual perception. These measures include: Visual Discrimination of Upper Case Letters; Visual Discrimination of Lower Case Letters; and Visual Discrimination of Numbers.

3. Create linear, uni-dimensional measures of letter and number recognition related to Spatial Orientation of Letters and Numbers and Letter and Number Sequencing.

4. Create linear, uni-dimensional measures of letter and number recognition related to Form Constancy of Letters and Numbers; Figure Ground Letters in Words and Figure Ground Numbers in Calculations.

5. Identify the students with the lowest measures and analyse the common features related to these students to determine the letter and number groups or student groups that require early intervention and extra attention.

6. Identify through qualitative interviewing the reasons why students with the lowest measures find it difficult to identify certain letters and numbers in isolation and in context.

Research Questions

Can letter and number identification and reversal tendencies be assessed and recognized using visual perceptual principles? To answer this question, the study and data collection process followed the following guiding questions:

1. Can a model of visual perceptual letter and number identification be created according to five operationally defined visual perceptual concepts (visual discrimination, visual spatial orientation, visual form constancy, visual sequencing and visual figure ground) to guide the creation of eight uni-dimensional linear scales to measure these constructs?

2. Can linear, uni-dimensional measures of letter and number recognition related to Visual Discrimination of Upper Case Letters; Visual Discrimination of Lower Case Letters; and Visual Discrimination of Numbers be created so that they are reliable and valid inferences can be drawn from them?

3. Can linear, uni-dimensional measures of letter and number recognition be created that relate to Spatial Orientation of Letters and Numbers and Letter and Number Sequencing so that they produce reliable measures from which valid inferences can be drawn?

4. Can linear, uni-dimensional measures of letter and number recognition be created that relate to Form Constancy of Letters and Numbers; Figure Ground Letters in Words and Figure Ground Numbers in Calculations so that they produce reliable measures from which valid inferences can be drawn?

5. Will identifying the students with the lowest measures and analysis of the common features related to these students allow accurate identification of the letter and number groups requiring additional attention in the early school years and in addition will it allow identification of student groups that require early intervention?

6. Can students with the lowest measures accurately identify the reasons why certain letters and numbers in isolation and in context are more difficult for them to identify than other letters and numbers? Can this information add to the pool of knowledge in order to assist students at risk in the area of literacy and numeracy in the early school years?

Significance of the Study

Many children diagnosed with learning disabilities, developmental delays, neurological impairment, and acquired brain injury present with visual perceptual dysfunction. These children require accurate assessment of the areas of difficulty in order to focus intervention on the exact areas that require attention. There are existing tests of letter and number reversal recognition skills (such as the *Jordan Left-Right Reversal Test, The Reversals Frequency Test* and the *Test of Pictures / Forms / Letters / Numbers Spatial Orientation & Sequencing Skills*) (M. F. Gardner, 1991; R. A. Gardner, 1978; Jordan, 1990), however these are dated, exhibit poor levels of reliability and validity, are non linear and were developed in the United States of America. These assessments also rely on the 'ball and stick' font, making it difficult to assess when a student is confusing 'b' and 'd', as these letters represent a valid letter in either orientation (d / b). Therefore, a new test of this type developed within a combined visual perceptual and occupational performance conceptual framework is urgently needed for occupational therapists and teachers that will accurately guide the intervention for students in Australia with these difficulties.

Letter and number recognition is required for learning to read, spell and complete calculations. Children often have difficulty learning these skills of reading, spelling and calculating due to difficulties with the visual perceptual concepts of visual discrimination, form constancy, visual sequencing visual spatial orientation as well as visual figure ground. To improve the skills required at school, the basic concepts of visual perception must be established. Accurate assessment of these basic visual perceptual concepts is important in order to determine at what level intervention must be aimed in order to appropriately remediate difficulties with reading, spelling or calculating. There are currently no accurate assessments of the basic visual perceptual concepts as they relate to letters and numbers that are linear, uni-dimensional and that identify students at risk.

This study is significant in that the gap in assessment tools for visual perceptual assessment related to letters and numbers was addressed. Three linear, uni-dimensional measures were created to assess visual discrimination using upper case letters, lower case letters and numbers. In addition linear, uni-dimensional measures were created to assess spatial orientation of letters and numbers, letter and number sequencing, form constancy of letters and numbers, figure ground of letters in words as well as figure ground of numbers in calculations. Linear, uni-dimensional scales allow the accurate arrangement of letters and numbers in each scale from easy to difficult. The skills of students are thus measured accurately leading to early identification of students at risk on each scale. Teachers are also empowered with these measures to identify the students at risk with ease and at an early stage of their schooling, guiding the teachers in producing tailored remedial programs for these students related to their weakness.

Some students with lowest measures were interviewed to determine why some letters and numbers are difficult for them to identify. The outcomes of these interviews guide teachers in reasoning about the type of font used when teaching students letters and numbers in the initial schooling years. This information will also give clues and assistance in how to cue students in learning the most difficult letters and numbers looking at discrimination of shape, spatial orientation, sequence and background.

Limitations of the Study

This study was applied in public and private primary schools within the Perth metropolitan area. Students in rural areas or in schools where teaching methods differ from the early teaching methods in these schools may experience the learning of letters and numbers in a different manner and will therefore find different items difficult. In addition, students learning letters and numbers in a different font from the Victorian Modern Cursive font such as students in Queensland and New South Wales may find different letters and numbers difficult to identify due to the difference in the font shape of some of the letters and numbers.

Some of the items created in the study did not fit the measurement model and were excluded from the data analysis. Letters that were excluded were commonly those that are confusing in the font used in this study; for example the reversed image of the upper case letter J which is easily confused as an L (l) in the Victorian Modern Cursive font. This means that not every letter and number is included in every scale. In addition it is also impossible to create measures that cover every combination and every context of letters and numbers.

Definition of Terms

The terms elaborated in this section define the meanings of these terms as they are used in the context of this study.

Visual discrimination of letters and numbers

Visual discrimination is related to the ability to visually differentiate (identify/ detect features of stimuli for recognition) small differences between similar looking forms such as b/d, shapes such as 5/s, symbols such as 'x' and '+' or objects; relate these key features to memory (matching) and categorise these forms, shapes, symbols or objects (grouping of stimuli based on common characteristics) in order to make sense of the written word or numbers.

Spatial orientation of letters and numbers

Visual spatial orientation involves the analysis of forms, shapes, figures and patterns in relation to one's body and space. The relationships between two or more forms, shapes, symbols or objects and between objects and the person lead to the development of the perception of spatial orientation in two or three-dimensional space. Visual spatial orientation will influence the way a person reads and writes letters, words and numbers, as the orientation of the letters and numbers is specific to the position on the page and to the surrounding letters and numbers on the page.

Form constancy of letters and numbers

Visual form constancy is the ability to match and correctly identify two forms, shapes, figures or objects that vary in one or more discriminating features (such as size, position, font or shade). This involves recognition of the dominant features of certain figures or shapes when they appear in different environments, sizes, shadings, textures and positions. Visual form constancy is the ability to identify an object, shape, symbol or form in reading, spelling and calculating as being the same, regardless of its size, shade, background, font or orientation in space.

Visual letter and number sequencing

Visual sequencing refers to the order in which forms, shapes, symbols or objects are produced visually such as in the printed word. Visual sequencing of letters and numbers will influence the way a person reads and writes words, sentences and numbers greater than nine or calculations, as the order of the letters and numbers is specific to the end result of the meaning represented by the letters in the words (such as saw and was), words in the sentence (such as 'he comes here' or 'here he comes') or numbers in the calculations (such as 59-9=50 or 95-9=86).

Visual figure ground using letters and numbers

Visual figure-ground is the ability to see specified shapes, forms, symbols or objects when they are hidden in confusing, complex backgrounds. This requires visual focus on selected detail in the environment and the ability to screen out irrelevant information. The person then pays attention to meaningful visual stimuli while ignoring the surrounding visual stimuli**.** Poor visual figure-ground will result in difficulty in isolating letters and numbers in order to identify them and use them meaningfully

Visual letter and number reversals

Visual letter and number reversals occur when children recognise or reproduce written symbols (such as letters or numbers) in the incorrect orientation, for example, when a student recognises or writes a ‘b’ as a ‘d’. The letters and numbers may be reversed in the left-right orientation or inverted in the top-bottom orientation such as confusing ‘n’ and ‘u’.

Simple Logistic Model of Rasch

The Simple Logistic Model of Rasch (often called the one-parameter logistic model within item response theory in the literature) involving the probability of a specified response to a set of items (such as score 0 for incorrect response and 1 for correct response) really contains two parameters, one for respondent (person) ability and one for item difficulty. The probability of a correct response is modeled as a logistic function of the difference between the person and item parameters. The parameters of the model pertain to the level of a quantitative trait possessed by a person or item, thus the stronger a person's ability relative to the difficulty of an item, the higher the probability of a correct response on that item. The model is used to obtain linear, uni-dimensional measurements from categorical response data, where the attribute must possess additivity and ordinality, and thus produce reliable measures from which valid inferences can be drawn (Acton, 2003).

Logits as units of Rasch Measurement

A ‘logit’ is the logarithmic odds of the probability of success or failure which produces equal interval linear measures from qualitatively ordered observations such as incorrect (score 0) and correct (score 1) . The logit scale is independent of the particular group of items that is included in a test at any particular time, or the sample of persons that are used to calibrate these items. When the data in logits fit the measurement model, the difference between any person and any item on the scale will always have the same outcome (Wright, 1993).

Dimensionality

In the RUMM2020 computer program, dimensionality is determined by an item-trait chi-square statistic that indicates whether there is good agreement, amongst all the respondents (persons), as to the difficulties of each of the items along the linear scale. The expected value is compared with the observed mean value of the responses that persons with the total score r, obtained on item I, summed over all items and all persons.

If the observed and expected values are not significantly different, then there is no significant interaction between the responses to the items and the location values of the persons along the linear scale (see Andrich & van Schoubroeck, 1989, pp. 479-480). This means that each person can be represented by one parameter (measure) across all items and each item by one parameter (difficulty) for all persons. This is what it means to be uni-dimensional.

Person Separation Index

In the RUMM2020 computer program, the Person Separation Index is constructed as the ratio of the estimated true variance among the persons and the estimated observed variance among the persons using the estimates of their locations and standard errors of those locations (person measures) (Andrich & van Schoubroeck, 1989, p. 483). Hence it is interpreted in a similar way to the Cronbach Alpha in traditional reliability (Cronbach, 1951). Another way to interpret it is whether the measures are well separated in comparison to the errors.

Cronbach Alpha

Cronbach's Alpha (Cronbach, 1951) is mathematically equivalent to the average of all possible split-half estimates of a scale and is used to measure the internal consistency reliability of a non-linear scale, but can be applied to linear scales as well.

Targeting

The person and item locations are estimated on a single scale in the form of a graph which allows comparison of the person distributions with the items distributions. From these estimates the relative difficulty of the items for the population can be assessed, indicating whether there are sufficient easy, medium and difficult items to assess that trait for the desired population.

Item Characteristic Curve

Item Characteristic Curves are produced by the RUMM2020 computer program (Andrich, Sheridan, & Luo, 2005) for each item and they show the expected values by person measures for various groups of persons along the scale. The characteristic curve is an ogive and, when the data fit the measurement model, the mean values for each group of persons fit the ogive well. Data can also be split into other groups (such as male and female) and plotted separately on the ogive to see whether there is any differential item functioning by gender (which can be uniform or non-uniform).

Scoring Category Curve

The Scoring Category Curve represents the probability of scoring in a given category as a function of person location (measure) along the linear scale (with the threshold between categories being the location on the linear scale at which a person is equally likely to obtain a score of 0 or 1). When the measures are low, the respondents should have a high probability of scoring in a low category. As the measures increase, the probability of scoring in a higher category should also increase so that, when the measures are high, the respondents should have a low probability of scoring in a low category and a high probability of scoring in a high category (Andrich, 1988).

Residuals

Residuals are the differences between the expected values, calculated according to the Rasch measurement model, and the actual values (Andrich, 1988).

Global Person and Item Fit Statistics

Global Person and Item Fit Statistics evaluate the response patterns for persons across items and for items across persons. Using the parameters calculated from the Rasch measurement model, each person's expected score on each item can be calculated and compared with the actual score to calculate residuals which are summed over all items for each person and summed over all persons for each item, and then standardised. When the data fit the measurement model, the standardized fit statistics approximated a distribution with a mean near zero and a standard deviation near one (Andrich, 1988).

Linking Linear Scales

While the Rasch-created scales are linear (equal differences between the numbers on the scale represent equal amounts of what is being measured), the zero point is arbitrary. Two separate Rasch-created linear scales can be equated (linked) by comparing the mean person measures and adding the difference to the lower student measured scale and then the measures on both scales (items and persons) can be validly compared. This equating method is called the Translation Constant method (Sadeghi, 2006).

Rasch Uni-dimensional Measurement Model Computer Program

The Rasch Uni-dimensional Measurement Model (RUMM) (Andrich et al., 2005) is used in this study to create the linear scales for measuring the visual perceptual constructs related to letter and number recognition. The RUMM computer program is considered to be one of the best programmes currently available to test the data for fit to the measurement model so that reliable linear scales can be created from which valid inferences can be made. Rasch measurement is explained in Chapter Four.

Structure of the Thesis

This thesis is made up of eleven chapters which report the introduction to the study, a literature review, the theoretical models and the evaluation of current published measures, Rasch measurement and the theoretical structure of the measures used in the present study, the methodology, eight Rasch data analysis measures, equating of measures, qualitative data analysis, and the discussions and implications. A summary of the chapter contents is provided in the following section.

Chapter Two

Chapter Two is a selective review of the literature related to concepts of visual perception and letter and number recognition. Attention was given to the anatomy and physiology of visual perception, the development of visual perception as well as the relationship between visual perception and the understanding of letters and numbers in printed text.

Chapter Three

Chapter Three discusses the major theoretical models that guide assessment and intervention of visual perception related to letter and number reversal and evaluates the three current main measures used in this field. Models informing the theory of visual perception, which guide the clinical reasoning of occupational therapists, are briefly outlined and explained in relation to the present study. Theoretical models of letter and number reversals, an important aspect of the current research study, are outlined. A critique of current tests of letter and number reversals is included as these all used True Score Theory measurement which can only produce a non-linear scale, and none have been standardised using modern measurement models like Rasch Measurement. Some problems with the current measures are explained.

Chapter Four

Chapter four addresses the measurement of visual perception as it is used in this study. Measurement is explained in general, and the differences between True Score Theory and Rasch Measurement are outlined. This is followed by specifics of the Simple Logistics Model of Rasch as it is applied to this study and links the RUMM 2020 (Andrich et al., 2005) computer program used to create a uni-dimensional linear scale for each of the measures used in this study. The theoretical structures of each of the eight variables used in the present study are described and these structures are tested in the data analysis chapters.

Chapter Five

Chapter Five explains the methodology and research design used in the present study in which eight linear uni-dimensional scales were created. Administrative and ethical approvals used in this study are first outlined. The planning and design of the study followed six stages: (1) Item and test development; (2) Test item content and definitions; (3) Item refinement and test assembly; (4) Data collection and data entry; (5) Data analysis; and (6) Reporting Rasch analysis results. These stages are elaborated in this chapter.

Chapter Six

Chapter Six presents an in-depth Rasch analysis of the first three uni-dimensional, linear scales that were created with the Rasch Uni-dimensional Measurement Models (RUMM2020) computer program (Andrich et al., 2005). These scales are: Visual Discrimination of Upper Case Letters; Visual Discrimination of Lower Case Letters and Visual Discrimination of Numbers. These scales are presented together as the scales relate to visual discrimination, whereas the other scales created relate to other visual perceptual concepts and are thus discussed separately. This chapter describes the measurement results in terms of Rasch measurement fit statistics including global item and person fit to the measurement model, dimensionality, person separation indices, distribution of item-person interactions, and discrimination. There is some discussion about the non-fitting items in addition to good fitting items and the person-item threshold distribution (targeting). This is followed by mean Rasch measures by group and final items for the Visual Discrimination Scales discussion. Finally, inferences drawn from the linear Rasch measurement data analysis and the summary of the results are presented.

Chapter Seven

Chapter Seven presents part two of the Rasch data analysis. This includes Spatial Orientation Letter and Numbers as well as Letter and Number Sequencing as these scales relate to the position of letters and numbers in relation to each other on the page (spatial position), whereas the other scales relate to other visual perceptual concepts. The measurement results are explained in terms of Rasch measurement fit statistics in summary form to avoid repetition of chapter six and includes global item and person fit to the measurement model, dimensionality, person separation indices, distribution of item-person interactions, and discrimination. Discussion of the non-fitting items as well as good fitting items and the person-item threshold distribution (targeting) is included. This is followed by mean Rasch measures by group and final items for the Spatial Orientation and Sequencing Scales discussion. Inferences drawn from the linear Rasch measurement data analysis and the summary of the results are also presented.

Chapter Eight

Chapter Eight (Part three of the data analysis) presents a Rasch analysis for three linear, uni-dimensional scales: (1) Form Constancy of Letters and Numbers, (2) Figure Ground of Letters in Words, and (3) Figure Ground of Numbers in Calculations. These three scales relate to the visual perceptual concepts of 'form constancy' and 'figure ground'. This chapter describes the measurement results in terms of Rasch measurement fit statistics including global item and person fit to the measurement model, dimensionality, person separation indices, distribution of item-person interactions, and discrimination. The non-fitting items, as well as good fitting items, and the person-item threshold distribution (targeting) are briefly discussed. Mean Rasch measures by group and final items for the Form Constancy and Figure Ground Scales discussion are outlined. Inferences drawn from the linear Rasch measurement data analysis and the summary of the results are presented.

Chapter Nine

Chapter Nine is a discussion on the RUMM output of data where students with the lowest measures for each of the eight, uni-dimensional linear scales relating to various aspects of letter and number discriminations and reversals scale were identified. This data is presented in relation to the responses of these students (identified only by number for ethical reasons) involving their inter-connections across measures in the eight scales. Inferences drawn from the inter-connections across the eight linear Rasch scales are presented.

Chapter Ten

Chapter Ten presents an analysis of qualitative data collected from younger students who achieved lower scores through focus group interviews. The data collected related to their responses on the eight uni-dimensional scales and their reasoning as to why they found certain letters and numbers more difficult to identify. This information is compared to the RUMM analysis results of the most difficult items through abstraction. The focus group interview data presented in this chapter assists in achieving understanding of how students in primary school learn their letters and numbers, as well as the reasoning behind the identification of letters and numbers.

Chapter Eleven

Chapter Eleven provides a discussion of the findings of the study which are focussed on addressing the research questions presented in the beginning of the study. The findings from the Rasch measurement analysis as well as the results of the focus group interviews are discussed in relation to the inferences made. Implications for teachers, students, parents and administrators together with recommendations for further research are explained.

The next chapter, Chapter Two provides a review of the relevant literature relating to this study.

CHAPTER TWO

LITERATURE REVIEW (Part 1)

This chapter reports a review of the literature which provides the relevant basic background to the present study. In keeping with the topic of visual perception, the anatomy, physiology, development, theoretical models and measurement of visual perception were investigated. Research relating to the connection between the eye and brain function related to the development of vision and visual perceptual skills is summarised. In addition, research showing the relationship between visual perception and academic performance is explained. Reference is also made to the effect of visual perception in certain clinical groups.

Anatomy and Physiology of Visual Perception

The acts of learning, memorising and perceiving occur over a number of areas of the nervous system (Marieb, 2001; Tortora & Grabowski, 2003). The complex interaction of these areas and the physiology of learning, memorising and perceiving is not yet fully understood (Tortora & Grabowski, 2003). However, the current level of knowledge about how the development and functioning of the brain and vision is related to visual perception is summarised.

The Nervous System

In humans, the nervous system begins to develop within weeks of conception and continues into the postnatal period (Erhardt & Duckman, 2005). The visual cortex is located in the posterior part of the brain on the medial side of each cerebral hemisphere and a small portion extends over the occipital lobe. The cerebral cortex is needed to interpret shapes, colours and movement. The cortex must be activated by the lower regions of the brain to call forth stored information (Guyton, 1979; Marieb, 2001; Tortora & Grabowski, 2003).

Specific cortical areas of the brain influence certain visual perceptual skills. Short-term or working memory and spatial orientation is thought to be controlled by the frontal and parietal lobes, while visual object recognition, right left discrimination, drawing skills and constructional concepts are controlled by the parietal lobe. The occipital lobe is thought to control general visual perception, and vision; and the temporal lobe analyses spatial (topographical) information as well as spatial and long-term memory (Grieve, 2000; Wilcock, 1986).

Functions of the brain related to learning

The cerebrum is said to be the 'seat of intelligence' and provides the ability to read, write, speak, calculate, make music, remember, plan and imagine (Tortora & Grabowski, 2003). It is believed that the sensory area and other areas of the parietal cortex are involved in directional sense, body image and academic learning of arithmetic, writing, spelling and reading (Gaddes, 1980). Motor pathways have an effect on academic learning especially in writing, spelling and drawing, but may also affect reading and arithmetic (Gaddes, 1980). Visual-motor abilities are hypothesised as being influenced by pyramidal and posterior cerebellar function.

The thalamus is the major relay station for most sensory impulses reaching the cerebral cortex (Schmidt, 1978). Words (shapes) are seen in the primary visual area, recognised (visual memory and constancy) in the visual association area and meanings of words are interpreted in the common integrative (gnostic) area (Lucas & Lowenberg, 1996; Tortora & Grabowski, 2003). Stimuli from the visual cortex and thalamus are sent to the visual association area of the cortex where interpretations of, and interrelations between objects and the identification of objects occur. Thus, the common association area puts all incoming stimuli into perspective and gives integrated meaning to it. From here, signals are sent to other areas of the brain for an appropriate response (Tortora & Grabowski, 2003).

The cerebellum is involved in thinking (cognition). The cerebellum functions in recognising and predicting complex sequences of events and may thus be involved in analysing letter and number sequences (Marieb, 2001). The posterior portion of the temporal lobe, and the adjacent region of the dominant hemisphere, is important to intellectual functioning. Prefrontal areas of the cerebral cortex are important in abstract thought which is involved in storing information at each step of the logical process in mathematics (Tortora & Grabowski, 2003). Nouns are processed in the left parietal region, while verbs are processed in the frontal lobe (Lane, 2005). When reading, the occipital region is activated by visual features of the letters, the angular gyrus transcribes print into language and Wernicke's region accesses meaning (Lane, 2005).

Memory and alertness is thought to occur in the association cortex of the frontal, parietal, occipital and temporal lobes, as well as in part of the limbic system. Long-term memory is stored in extensive areas of the cerebral cortex (Tortora & Grabowski, 2003). Memory is used during the process of visual perception and reading when the printed word has to be compared with previous information in order to be identified and the complete sentence or paragraph must be remembered to derive meaning from what is seen and read. This is relevant to the current study in the sequencing scales and figure ground scales where the student is expected to remember or recognise words and sequences in order to identify whether they are correct or incorrect.

The Eye

The eye is the receptor organ for sensory input leading to visual perception as well as the ability to read and understand what is been read. When the eye is not functioning optimally, the sensory input will not be received correctly resulting in dysfunctional visual perception and reading difficulty.

Development and structure of the eye

The wall of the eye ball consists of three layers: the fibrous tunic (consisting of the anterior cornea and posterior sclera), the vascular tunic and the retina. The cornea assists in focusing light into the retina. The vascular tunic (uvea) consists of the choroid which lines the sclera, the ciliary body which alters the shape of the lens for adaptation to near and far vision and the iris which regulates the amount of light entering through the pupil. The retina is the beginning of the visual pathway. Visual data is extensively processed in the neural layer (multilayered outgrowth of the brain) of the retina prior to nerve impulses being sent to the optic nerves. Vision provides the sensory information for use in making spatial judgements (Guyton, 1979; Hothersall, 1985; Marieb, 2001; Tortora & Grabowski, 2003) as every cell in the retina of the eye corresponds to a single location in space (Erhardt & Duckman, 2005). These spatial judgements, associated with letter and number orientation inform the spatial orientation and visual discrimination scales in the current study.

Development and physiology of vision

The interpretation of visual information is a complex process involving 32 separate areas of the cortex which are connected to 187 neural pathways (Gray, 2002). The eyes move in a series of quick movements, called saccades and pause to take in visual information during fixations (Warren, 1993). When the eyes move, there is no visual perception (Lane, 2005). The amount of information available to the brain during the fixation is the perceptual span or span of recognition (Lane, 2005). Optic fibres transmit information via the primary visual cortex, where visual input is mapped topographically with a particular area of the cortex corresponding to a particular point on the retina (Gray, 2002). Information is simultaneously transmitted via the visual association area to those specific areas dedicated to the analysis of particular visual features such as colour, form and motion. The final integration of the information into a coherent interpretation depends on complex interactions between a large number of cortical areas working in parallel (Gray, 2002; Lane, 2005). Analysis of the visual image begins in the retina, and is interpreted in the cortex (Guyton, 1979; Marieb, 2001), where previous experiences (memory) are combined with perception of what is seen to derive meaning (Guyton, 1979; Marieb, 2001; Tortora & Grabowski, 2003). Complex visual processing involves two visual streams. One runs along the top of the brain and interprets object identity and the other runs lower down and focuses on object locations (Marieb, 2001). Both visual streams are incorporated in the current study when the student is expected to identify letters and numbers in the correct or reversed orientation individually (object identity) as well as in words, sequences and mathematical calculations (object location).

Visual Components related to visual perception

Vision provides the sensory information on which all spatial judgements are made. Visual acuity is the ability of the eyes to resolve detail to enable the correct identification of information in space which is a prerequisite of effective reading skills. Accommodation (eye focusing) of the eyes assists in resolving detail of stimuli presented in near space. During vision a series of eye movements occur which allow perception to take place. Localisation is the ability to quickly and accurately localise a visual target while fixation is the ability to maintain a stationary gaze. Ocular pursuit allows smooth tracking of an object and gaze shift allows quick, accurate movement of the eyes independently of the head, thus allowing visual tracking of objects (Erhardt &

Duckman, 2005). Visual tracking is relevant to the current study as students are expected to scan a page for the relevant information required, such as the reversed letters in words or reversed numbers in calculations.

Overview of Visual Perception

The process of visual perception is complex, involving many areas of the cerebral cortex, thalamus, epithalamus, subthalamus, cerebellum and limbic system. The visual stimulus for the visual perceptual process is derived through the eye, cortex and the associated areas. The development of visual perception and meaning evolves through time and experience.

This overview will cover the development of visual perception, the types of visual perception found in tests of visual perceptual skills frequently used by occupational therapists, types of visual perceptual problems found in diagnostic groups seen by occupational therapists and the relationship of visual perception to academic areas of student performance, including the influence on letter and number reversals that occur in reading and spelling.

Definitions of Visual Perception

Perception refers to the reception and interpretation of a stimulus received from the environment, rather than its sensory or symbolic aspects (Erhardt & Duckman, 2005). This would suggest that visual perception is the effective receiving and transforming of visual sensations or stimuli into electrical impulses that have appropriate meaning to the individual. As such, visual perception allows individuals to interpret and make accurate judgments of the size, configuration and spatial relationships of objects in their environment (Frostig & Horne, 1964; Kranowitz, 1998; Schneck, 1996, 2005).

Kulp (1999) also referred to visual perception as the process of organising and deciphering visual information, while Kirk and Gallagher (2000) suggested that children interpret the environment through the significance of what was seen. Thus visual perception is described as the ultimate skill to manage the images and symbols on a page and make sense of them. Loikith (1997) determined that "visual perception is a dynamic cognitive effort that at once involves memory, strategic knowledge, short-term memory and attention to satisfy a visual task demand or goal" (p. 218). This visual task may be reading, spelling or interpreting what is read.

Gardner (1992) stated that visual perception included what the person does with what is seen, although it does not measure sight. Thus, 'visual perception' could be referred to as the ability of the brain to understand and interpret or make sense of the sensory stimulus of what the eyes see and based on this understanding and interpretation, the person would be able to express the meaning verbally or motorically (M. F. Gardner, 1992). In summary, visual perception can be viewed as the ability to use visual information to recognize, recall, discriminate and give meaning to what the eyes see, and if necessary give an appropriate motor or verbal response that holds meaning for the individual as well as other people receiving that response. Thus, the person sees the written form of language, interprets the symbols, and is able to read with meaning.

Categories of Visual Perception

A number of theorists have identified categories of visual perception, which are seen as separate, although inter-related entities (Frostig, Lefever, & Whittlesey, 1966). The visual perceptual categories identified by theorists are discussed below according to the terminology used in existing tests of visual perception and are related to reading (Beery, 1997; Fisher, Murray, & Bundy, 1991; M. F. Gardner, 1996; Hammill, Pearson, & Voress, 1993). This is of relevance to the current study because letter and number identification and reversal of letters and numbers are assessed in a variety of visual perceptual contexts related to reading and mathematics.

Visual discrimination

Visual discrimination is the ability to perceive sensory information entering the brain in an expedient manner, and differentiate or recognise similarities and differences (distinctive features) in forms, shapes, symbols or objects (Edwards, 1987b; Grove & Haupfleisch, 1978; Todd, 1999) such as matching or separating colours, shapes, numbers, letters, and words (Kranowitz, 1998). Part of visual discrimination is being able to differentiate between two pictures or words (Kirk et al., 2000; Levine, 1991; Todd, 1999). Visual discrimination in the detection and matching of stimulus characteristics appears to precede the ability to differentiate changes in position (Todd, 1999).

Visual discrimination is further described as the ability to detect features of stimuli for recognition (ability to note key features and relate them to memory), matching (identification of stimuli that are exactly alike) and categorisation (grouping of stimuli based on common characteristics) (Schneck, 1996; Todd, 1999). Thus visual discrimination is the ability to visually differentiate (identify) small differences between similar looking forms such as b/d, shapes such as 5/s, symbols such as 'x' and '+' or objects in order to make sense of the written word or numbers.

Position-in-space

Position-in-space has been defined as the perception of the relationship of figures and objects to oneself (Frostig & Horne, 1964; Grove & Haupfleisch, 1978; Schneck, 2005). In the DTVP-2 (Hammill et al., 1993), position-in-space is said to be the ability to "match two figures according to their common features" (p. 26). They added that position-in-space involved discrimination of reversals and rotations of figures. Another definition states that position-in-space is the awareness of the spatial orientation of letters such as 'b' and 'd', words such as 'was' and 'saw', numbers as in '6' and '9', or drawings on a page, or of an object in the environment for example seeing that a tree trunk is below the leaves (Kranowitz, 1998). However, Edwards (1987a) observed that a child must know where his/her body is in relation to objects and how to navigate around them, and that this is the perception of position-in-space. Thus, position-in-space is the perception of the position/orientation of an object in relation to the person or a direction in two or three-dimensional space. This implies that difficulty in identifying the position of a two-dimensional object in space will result in difficulty with reading and mathematics.

Visual figure-ground

The human brain is able to select a limited number of stimuli, which become the centre of attention, from a mass of incoming stimuli. The selected stimuli form the figure in the person's perceptual field, while the majority of stimuli form a dimly perceived background (Frostig & Horne, 1964; Grove & Haupfleisch, 1978; Kranowitz, 1998; Schneck, 2005). An object cannot be perceived accurately unless it is perceived in relation to its background (Frostig & Horne, 1964). For example, a person looking at a map has to separate the writing from the drawings in order to find the name of a town, or a person looking up a telephone number in a directory needs to read each line separately in order to locate the specific name and number the person is looking for.

Hammill et al. (1993), as well as Kirk and Gallagher (2000), describe figure-ground as the ability to see specified figures even when they are hidden in confusing, complex backgrounds. Additionally, children learn to focus visually on selected detail in the environment and to screen out irrelevant information (Edwards, 1987b). In summary figure-ground is the ability to pay attention to meaningful visual stimuli while ignoring the surrounding visual stimuli. Poor visual figure-ground will result in difficulty in isolating letters and numbers in order to identify them and use them meaningfully when reading or performing mathematical calculations.

Visual spatial relationships

Spatial relationships develop out of the ability to perceive the position of two or more objects in relation to the body and in relation to each other and therefore, develop at a later age than position-in-space (Frostig & Horne, 1964; Grove & Haupfleisch, 1978; Levine, 1991). Different parts perceived in relation to each other are not perceived simultaneously, but in temporal sequence and integrated into a total picture (Grove & Haupfleisch, 1978). The right cerebral hemisphere has been associated with the function of visual spatial relationship perception (Fisher et al., 1991).

The DTVP-2 (Hammill et al., 1993) purports that spatial relationship skills involve the analysis of forms and patterns in relation to one's body and space. Edwards (1987a) reported that the child learns about the relationships between objects and between objects and him/herself leading to the development of the perception of spatial relationships in a two or three-dimensional space. According to Levine (1991) children acquire spatial orientation concepts in the developmental sequence of vertical dimension first, followed by horizontal, and lastly oblique and diagonal dimensions. In summary spatial relations can be defined as the perception of the relationship between two or more objects in relation to the person and in relation to each other in two or three-dimensional space. Thus, visual spatial relationships would have an influence on the way we read and write letters, words and numbers, as the orientation of the letters and numbers is specific to the position on the page and to the surrounding letters and numbers on the page.

Form constancy

Some authors report that children learn to recognise the unique shape, size and positional characteristics of objects through touch, movement and vision and that when objects appear to change size, shape or position, they are still similar despite the variability of the impression (Frostig & Horne, 1964; Grove & Haupfleisch, 1978; Levine, 1991). It can therefore be expected that children will be able to identify letters and numbers without confusion in a variety of context, size and font (style and size of type) such as handwritten, typed or a variety of printed fonts. Developed form constancy would also enable children to identify and match letters in their upper and lower case form e.g. b and B, when reading, writing or spelling.

Hammill et al. (1993) define form constancy as the ability to match two figures that vary in one or more discriminating features (such as size, position, or shade). This involves recognition of the dominant features of certain figures or shapes when they appear in different sizes, shadings, textures and positions. Schneck (1996) agreed with this conceptualisation and described form constancy as the recognition of forms and objects as the same in various environments, positions and sizes. Form constancy can thus be defined as the ability to identify an object, shape, symbol or form as being the same, regardless of its size, shade, background or orientation in space.

Visual closure

Visual closure has been identified as the ability to recognise the whole when only a part is seen (Hammill et al., 1993; Kirk et al., 2000; Schneck, 2005). Thus, visual closure can be defined as the ability to identify the whole form or object from a partially completed form or object. This skill would enable a child to synthesise letters spelled out to form a whole word (as in s-p-e-l-l → spell), assist the child in spelling correctly and completing sentences and mathematical equations.

Visual memory

Visual memory has been defined as "the ability to retain and recall visual experiences" (Todd, 1999, p. 211). Three processes are fundamental to visual memory:

1. Registration (ability to attend to information for it to be stored);
2. Coding (understanding and structuring information); and
3. Retrieval (finding information stored in long-term memory) (Todd, 1999).

Visual short-term (working) memory is memory for information perceived by the eyes (sensory memory) where information is held for several seconds (Edwards, 1987b; Grieve, 2000; Loikith, 1997). Long-term memory retains information for periods from a few minutes to years (Grieve, 2000). Thus short-term memory will be used actively when learning letter and number direction, learning to read, write and calculate and long-term memory is used for recalling learned spelling, story lines, tables and simple mathematical rules.

Working memory has a limited capacity and consists of two components: an auditory loop and a visuospatial store where visual and spatial information that cannot be rehearsed verbally (such as space, colour, size and distance), and is temporarily stored (Collette, Salmon, Van der Linden, Degueldre, & Franck, 1997; Grieve, 2000). The sensory information entering the brain is processed briefly in the short-term memory prior to being passed on to the other components of the perceptual and cognitive system. Working memory enables the temporary storage of information while incoming data is actively processed and information from the long-term memory (storage) is retrieved (Collette et al., 1997; Vicari, Bellucci, & Carlesimo, 2003). Thus working memory plays an important role in temporary storage of letters and numbers while the child works out the word or answer to the equation which these letters and numbers make up.

In contrast, visual long-term memory has an unlimited capacity and processes a large variety of information for meaning and context, which can be stored for an unlimited time until it is retrieved by the short-term memory in order to activate a relevant response (Grieve, 2000). For example, an image of the face of a school friend will be stored in the person's long-term memory for many years, but on seeing the friend after a number of years, the image will be brought into short-term memory where recognition of the friend occurs and where the name is matched to the face. Similarly, the spelling of words and letter formation can be stored for a long time in long-term memory to be recalled to short-term memory when needed in order to write or read the word or letters. Visual memory is the ability to recall previous visually presented stimuli that must be retained for a short period of time and so is important in the process of reading, spelling and completing mathematical computations.

Visual sequential memory

Visual sequential memory is defined as the ability to remember things in the correct sequence in which they were perceived or presented (Edwards, 1987b). Research (M. F. Gardner, 1996) has shown that visual sequential memory is the ability to remember and recall a series of forms in the correct sequence in which it was visually presented. Visual sequential memory enables the person to remember what order letters appear in a word, such as the 'e' and the 'i' in 'receive'. Visual sequential memory also enables individuals to recall a series of written directions when unable to constantly refer to the printed visual stimulus. Visual sequential memory can be defined as the ability to remember a series of objects presented visually in the correct consecutive order and is thus used by children when reading, spelling and following directions or in solving mathematical formulae.

Visual reversals

Visual reversal occurs when children recognise written symbols (such as letters or numbers) in the incorrect orientation, for example, when a student recognises a 'b' as a 'd'. Some researchers found that children who continue to confuse letters such as 'b' and 'd' when writing are more likely to be able to perceive the visual differences between the letters, but have not learned which phoneme is associated with which letter. Letter reversals are generally thought to be associated primarily with language deficits (Catts & Kamhi, 1999; Fisher et al., 1991). Levine (1991), in contrast, concluded that visual spatial confusion leads to difficulty recognising letters and numbers in the early school grades. Some reversals and left-right confusion are associated with the normal development and maturation of the nervous system of children up to the age of seven years (Hope, 1994; Lane, 1988). Lane (1988) suggests that a child needs a mental age of five years six month to six years six months to overcome up-down reversals and a mental age of seven years and six months to overcome right-left reversals.

Boone (1986) researched the relationship of left-right reversals to academic achievement. Boone identified two areas of functioning where reversals occur: 'manual encoding' such as writing and 'visual receptive functioning' where symbols are not recognised in the correct spatial arrangement. A number of research studies have indicated that children who continue to make reversal errors beyond the norm have exhibited poor visual-motor skills and tend to make less progress in reading (Boon, 1986). Cohn (cited in Boon, 1986, p. 29) concluded that letter and word recognition difficulties indicates immature perception that naturally improves with time. However, numerous studies cited by Boone (1986) revealed significant relationships between lateral awareness (hemisphere specialisation), directionality (left-right discrimination) and academic achievement. These findings indicate that reversal tendencies and visual perceptual deficiencies are not restricted to any one particular academic area, but include aspects of them all. Reversal tendencies appeared to be more closely related to lower achievement in reading and language. Boone (1986) also confirmed that adequate visual discrimination abilities are a necessary prerequisite skill for successful instruction in academic subjects (Boon, 1986). Thus, letter and number reversal recognition skills are closely related to visual perceptual skills and are therefore frequently evaluated by paediatric occupational therapists.

Developmental Theories of Visual Perception

Cherry, Godwin and Staples (1989) suggest that the sequence of development of perceptual-motor skills occurs in three phases. The first phase is 'sensory-motor development' where an infant or toddler learns to respond motorically to their sensory environment and kinaesthetic awareness, and incidental movement produces a response as the child accidentally hits a rattle and a sound results. This is followed by the second phase of 'motor-perceptual development' where the child develops a perception of what the motor act will bring about, as when the child deliberately reaches for and grasps a toy. The third phase is the 'perceptual-motor development' where the child deliberately repeats an act through trial and error in order to achieve an expected result.

Perceptual-motor activities develop into concept formation (Cherry et al., 1989). For example a child who plays with a block will develop the concept of a square and realise that blocks can be stacked, while balls cannot be stacked. Kephart (1960) placed learning in similar predictable stages, with the earliest learning occurring exclusively as a result of motor actions, which result in a child's perception of the environment. As the child matures, perceptions control motor behaviour resulting in perception and cognitive processes becoming more central. Developmental theorists follow similar divisions in describing the development of perception as evidenced in Table 2.2.

The achievement of laterality and directional concepts for the correct formation of letters in writing, the correct left-right eye progression in reading and the correct direction of movement along a number line can be correlated to the beginning of Piaget's developmental stage of concrete operations (Cherry et al., 1989; Edwards, 1987a, 1987b). Piaget's fourth phase, formal operations, can be associated with the last of Kephart's primary stages of sensory-motor and perceptual-motor development where the child starts reasoning on an abstract level without concrete aids (Fisher et al., 1991). "This process of whole child development will now go on to further learning, achieving and maturing" (Cherry et al., 1989. p. 75).

Edwards (1987a), Kephart (1960), Hanneford (1995) and Piaget (1969) all agree that linear processing and concrete thought occurs mainly between the ages of four to seven years. This is the level at which most children begin to learn the skills of reading, writing and mathematics at school and includes learning the directionality of letters and numbers. Therefore, it is important to ensure that adequate intervention occurs to foster optimal development and academic performance in children at this age level.

In summary (see Table 2.1), researchers are in close agreement that the optimum period in the maturity of children for the development of visual perception is prior to, and overlapping, the first years at school (four to seven years). Visual perceptual skills continue developing up to 12 years of age. This identifies the period where assessment and intervention of delayed visual perception is most likely to occur and where intervention would be most beneficial. In addition this also identifies the time when children begin to learn new concepts such as reading, spelling, writing, calculating and developing complex visual reasoning and comprehension.

Table 2.1:

Summary of developmental theories related to the ages four to ten years

AUTHOR	*AGE*	*DEVELOPMENTAL LEVEL*
Frostig and Horne (1964)	+- 3 – 7 years	• Maximum perceptual development
	7 or 8 years	• Higher cognitive processes
Cherry, Godwin & Staples (1989)	Infancy	• Sensory motor development
	+- 7 years	• Motor-perceptual development • Perceptual motor development and laterality
Piaget (1969)	Birth- 2 years	• Sensory motor development
	2 – 5 years	• Pre-operational – use of language and classification
	5 -9 years	• Concrete operations – logical thought
	9 years onwards	• Formal operational – logical abstract thoughts
Kephart (1991)		• Last stage of sensory-motor and perceptual motor development
Hanneford (1995)	4 ½ - 7 years	• Gestalt hemisphere elaboration – whole picture processing/cognition occurs
	7 - 9 years	• Logic hemisphere elaboration – detail & linear processing/cognition, refining elements of language, reading, writing, linear maths progression.
	8 years onward	• Frontal lobe elaboration – Fine motor development/skills refinement with fine motor-eye teaming
	9 – 12 years	• Increased corpus callosum elaboration and myelination
	12 years onwards	• Whole brain processing
Edwards (1987)	7 – 8 years	• Development of directional concepts for correct letter formation in writing, left to right eye progression in reading and direction on number line
	11 years	• Reasoning on abstract level without concrete aids

Note: Summarised by the author from: Cherry et al., 1989; Edwards, 1987a; Frostig & Horne, 1964; Hanneford, 1995; Piaget, 1969.

Interaction of Visual Perception and Academic Performance

In the previous section an overview of visual perception was presented as a component of development and learning. Here, research findings related specifically to the influence of visual perception on academic learning are summarised, compared and contrasted. The analysis of these research findings includes definitions of academic performance and the influence of visual perceptual skills particularly in relation to reading, spelling and mathematics.

For satisfactory academic development it is expected that children perform adequately for the age or grade level of a child in the areas of reading, spelling, writing, mathematical computations, communicating, science, computers and sports, among other areas of academic performance (Erhardt & Duckman, 2005; Kirk et al., 2000; Loikith, 1997). Performance or expectation may refer to the child's individual intellectual quotient based on performance on a psychological intelligence test or the level of performance expected at the child's age or grade level (Kranowitz, 1998). Academic learning can also be described as the development of conceptual skills, such as learning to read words and multiply numbers, and to apply, compare, contrast and integrate newly learned skills with what one learned previously in other contexts of life (Kranowitz, 1998). In contrast, academic disability or difficulty refers to those school performances that fall below the level reasonably expected of a particular child at a specific grade level and chronological age in relation to reading, writing, spelling and arithmetic skills (Kirk et al., 2000).

Carrow-Woolfolk (1981) has previously correlated the role perception played in the developmental aspects of language and learning. She describes four dimensions of learning including: (1) cognitive behaviour that translates external information and relationships into internal representations by means of perception and memory; (2) linguistic knowledge; (3) language performance; and (4) the communicative environment. Concepts of space are dependant to a great extent on visual perception and are reflected in language in words that explain size, shape, colour, number, position, direction and distance. Comprehension of these words and concepts in, for example, listening, reading, mathematics and geography reflect the adequacy of the visual spatial functions of the individual (Carrow-Woolfolk, 1981). Attributes of objects are received through the visual channel, then recognised and remembered in perceptual categories and concepts. Visual discrimination and memory are essential to concepts associated with words and in the formation of new perceptions and classifications (Carrow-Woolfolk, 1981).

Kulp's (1999) findings in research conducted on 191 children enrolled in kindergarten through to third grade in the United States of America, supported Frostig and Horne's (1964) theory that visual perceptual skills were frequently related to learning readiness and academic achievement in reading, maths, spelling and writing, particularly in the first years at school. This was substantiated by significant correlations between educator ratings of classroom performance in reading, mathematics, spelling and writing ability and standardised test scores of visual analysis and fine motor integration (Kulp, 1999). In addition, Loikith (1997) outlined the importance of efficient and effective perceptual processing on school performance, especially when learning to recognise and differentiate letter and number forms.

Influence of visual perception in reading

Sorter and Kulp (2003) and Frostig et al. (1966) found a similar correlation of reading achievement and visual perception as measured on the *Developmental Test of Visual-Motor Integration* (Beery, 1997) and the first edition of *The Developmental Test of Visual Perception*, (Frostig et al., 1966). Similarly, Carrow-Woolfolk (1981) reasoned that visual perception was related to reading in that the letters are received through the visual channel first. Adequacy of the ability to recognise differences and visual sequential memory are important abilities in reception of words in reading and the ability to write (Carrow-Woolfolk, 1981).

Some researchers (Edelsky, 2006; Truch, 1991) believe that students read by using internal reasoning, a process of looking at the whole word by predicting or hypothesising and correcting words when they realise the sentence does not make sense, such as when a student reads 'bran' for 'barn'. Others (Green & Chee, 1997), however believe reading involves learning some 'sight words', followed by the ability to decode new, unfamiliar words by breaking them down into their component parts. At the age of six to seven years during the end of the phase of maximum visual perceptual development (Frostig & Horne, 1964; Hanneford, 1995), the majority of children begin to recognise words (Lucas & Lowenberg, 1996), while the majority of children at the age of seven to eight years, enter the phase of development of directional concepts and concrete operations (Edwards, 1987b; Hanneford, 1995), and could be fluent readers but not all enjoy reading (Goldstand, Koslowe, & Parush, 2005; Lucas & Lowenberg, 1996).

The components of reading are identified as a complex cognitive activity that consists of visual decoding, including configurational (feature) and orthographic (word form) analysis; and language comprehension including phonological, semantic and syntactic decoding (Catts & Kamhi, 1999; Green & Chee, 1997; Lachmann & Geyer, 2003; Wolf, 2008). Weak readers who have difficulty with shape recognition are described in the research literature as having 'visual perceptual dyslexia' (Green & Chee, 1997) or 'visual-orthographic deficit' (Badian, 2005). These readers have significantly lower reading variables than those without the deficit, since they have to sound out each word and confuse letters such as "b" and "d" beyond the first grade (Badian, 2005; Green & Chee, 1997).

The visual function involved in reading is considered to be a highly specialised, fast and accurate desymbolization of visual icons. Visual functions operate in parallel and are guided by memory (long term memory and working memory) and attention processes (Lachmann & Geyer, 2003). Decoding for reading is regarded as developmentally more applicable to children learning to read, whereas complex thinking is more applicable to older children and adults who read to learn. In this case, the decoding process would be the level at which visual perceptual skills would be required for recognition of letters and words (Catts & Kamhi, 1999; Goldstand et al., 2005; Kulp, 1999; Lachmann & Geyer, 2003). Accurate, effortless word recognition requires the use of visual decoding based on familiar letter sequences or graphic configuration and orthographic patterns (order of letters), while phonological skills (sounds represented) are necessary to develop proficient word recognition and semantics (meaning). The complex nature of reading indicates sub-types of reading difficulties, involving difficulty with grapheme-phoneme and phonological decoding or difficulty with visual spatial perception and thus the perception of letters and words as visual gestalts (Catts & Kamhi, 1999; Schneck, 2005). Furthermore, the complexity of reading is reflected in the pre-representational skills involved in reading which include the temporal integration of visual information and coordination between the visual system and the brain (Lachmann & Geyer, 2003).

Reading disability can be defined as a functional coordination deficit (Lachmann & Geyer, 2003). Reversals are only a small portion of errors made by poor readers, with vowel substitutions and consonant omissions, additions and substitutions occurring more often (Lachmann & Geyer, 2003). The underlying causes of reading problems may differ between beginning readers and poor readers, as well as between poor readers depending on the pattern of reading performance (Lachmann & Geyer, 2003; Oliver, Dale, & Plomin, 2007; Schneck, 2005). Reversals do not predict the performance on reading tests in young children, but are a good predictor of performance on reading tests for grade 3 children. Children who display more difficulties discriminating orientationally-related letters or patterns show more reversals in reading text. This is seen as evidence that difficulties in learning to read are related to suppressing mirror images generated in the brain when visual symbols are viewed (Lachmann & Geyer, 2003).

Some authors state that letter discrimination (the ability to see the visual differences between letters) and letter identification processes (knowledge of the correspondence between letters and phonemes), as well as visual attention and memory, are involved in reading (Catts & Kamhi, 1999; Schneck, 1996). There is general agreement that deficits in visual or attentional processes only play a casual role in reading disabilities and that, in terms of the percentage of overall errors, reversal errors were no more prevalent in young poor readers than in young good readers but, children with reading difficulties, continue to make reversal errors in later grades (Catts & Kamhi, 1999; Griffin, Birch, Bateman, & De Land, 1993).

Cherry, Godwin and Staples (1989) suggest that people who have difficulty remembering a letter sequence may also have difficulty reading and performing other structured academic tasks that are dependant on following a sequence of letters. Fisher, Murray and Bundy (1991) found that the complexity of academic tasks allowed for the involvement of both hemispheres to be involved in learning to read. However the left hemisphere appeared to be more strongly related to learning to read and comprehension.

In summary (see Table 2.2), it can be concluded from the material cited above that a child must have developed optimal visual and auditory discrimination, visual and auditory memory, part-whole processing, spatial orientation (to avoid reversals and inversions), retaining of visual sequences, and visual analysis and synthesis as well as other abilities in order to develop proficient reading skills (Catts & Kamhi, 1999; Cherry et al., 1989; Frostig et al., 1966; Green & Chee, 1997; Kulp, 1999).

Table 2.2

Summary of visual perceptual theory related to reading

Author	*Visual perception related to reading*
Frostig (1966)	Poor visual perception on DTVP resulted in poor reading achievement in Grades 2 & 3
Green & Chee (1997)	Reading problems stem from difficulty with shape recognition, phonic awareness, segmentation or a combination of these
Catts & Kamhi (1999), Kulp (1999)	Learning to read required decoding and use of visual perceptual skills for letter & word recognition
Catts & Kamhi (1999)	Reversals was equally prevalent in young good and weak readers, but was more prevalent in those continuing with reading difficulties
Schneck (1996)	Discrimination, visual attention and memory were required to read.
Cherry, Godwin & Staples (1989)	People with difficulty remembering a sequence, have difficulty reading

Note: Summarised by the author from: Catts & Kamhi, 1999; Cherry et al., 1989; Frostig et al., 1966; Green & Chee, 1997; Kulp, 1999; Schneck, 1996.

Influence of visual perception on spelling

According to Waters, Bruck and Marcus-Abramowitz (1988) the child must be proficient in reading as well as spelling in order to become literate. Their research compared good and poor spellers in various spelling tasks in order to determine the processes children used in spelling. They concluded that children are better able to use orthographic rules for spelling (those that relate to conventional spelling patterns) rather than morphological rules (that relate to units of meaning such as roots and morphemes such as ‘s’ denoting a plural). The performance of poor spellers relative to good spellers improved more with recognition, suggesting that poor spellers rely more on visual information than good spellers. Waters et al. (1988) also commented that performance on dictation tasks reflected the specific memories of the spelling words rather than general knowledge of spelling patterns. A further possibility was that patterns of performance reflected children’s sensitivity to visual rather than linguistic properties of word classes (Waters et al., 1988), hence the need for valid and reliable assessment instruments.

Levine (1991) and Schneck (1996) determined that weak visual perception and impaired processing of simultaneous visual stimuli could also cause difficulty with learning sight words and spelling. These authors also stated that visual sequential memory was necessary for remembering the sequence of letters in a word (Levine, 1991; Schneck, 1996).

Catts and Kamhi (1999) as well as Nielson et al, (2003; Nielson, Waugh, & Konza, 2009) found that writing was an excellent medium for developing a basic understanding of sounds and spelling for words, as writing required children to think about sound-letter correspondences, the relation of print to spoken language and orthographic/spelling patterns. In contrast, Siegel (1999) found that dysgraphia, a disorder of written expression may result in poor grammar. In summary (see Table 2.3), it appears that learners with poor spelling may rely more on visual perceptual skills in order to recall words than those with better spelling ability.

Table 2.3

Summary of visual perceptual skills related to spelling

Author	*Visual perceptual skills related to spelling*
Waters, Bruck & Marcus-Abramowitz (1988)	Poor spellers rely more on visual information
Levine (1991)	Poor visual perception results in difficulty learning sight words & spelling
Schneck (1996)	Visual sequential memory is important for sequencing in spelling

Note: Summarised by the author from: Levine (1991); Schneck (1996) and Walters et al (1988)

Influence of visual perception on mathematics

Children having difficulty with the mechanics of mathematics (dyscalculia) are slow to grasp the relative size of figures, to learn tables, to remember the sequencing of digits, and to understand the meaning of mathematical signs or master fractions (Green & Chee, 1997). To manage mathematics as an academic subject, children need to use visual imagery in order to display planning, problem solving, and organisation, as well as have a good working memory (Green & Chee, 1997; Loikith, 1997). This link between symbolic language and mathematics was also identified by Johnson and

Myklebust (1978), who found that the practical function in mathematics was to express quantitative and spatial relationships and the theoretical function in mathematics was to facilitate thinking. In addition, Lucas and Lowenberg (1996) separated mathematical concepts into two major aspects: (1) recognition and manipulation of numbers, and (2) acquisition and application of the language of mathematics, which in turn makes problem solving possible.

To carry out mathematical computations, children must have an understanding or grasp of basic perceptions of shape, space, symbols, copying and numeracy (Chinn, 2002; T. Miles, Chinn, & Peer, 2000; Schneck, 1996). Furthermore, the manipulation of numbers in mathematics also requires good visual perceptual skills such as visual discrimination, directionality, sequencing, organisation of work (spatial), correct alignment of columns for calculation (placement of number values), figure ground and memory (Chinn, 2002). For example, many rows of calculations on a worksheet could be disorganising for the child with figure-ground problems. Spatial perceptual skills are required in geometry and visual memory is required when multiple steps are required in a sum (Schneck, 1996). A number of authors agree that to solve mathematical problems, understand geometric relationships and use graphs, children require recognition skills, the ability to discriminate and the ability to compare objects, form and space (including inversions, rotations and distortions) (Chinn, 2002; Fisher et al., 1991; Hung, Fisher, & Cremak, 1987; Levine, 1991; Schneck, 1996).

Siegel (1999) described dyscalculia as "a crippling ailment that prevents one from learning math" (p. 305), while others (Fisher et al., 1991; Lucas & Lowenberg, 1996) found that difficulties with language may affect mathematical skills in the area of problem solving where problems are written in words rather than numbers. It has also been found that some learners had specific learning difficulties in mathematics where they could manipulate numbers orally and mentally, but were unable to record the responses as mathematical manipulations were primarily conducted in the right cerebral hemisphere of the brain while writing was primarily conducted in the left cerebral hemisphere (Fisher et al., 1991; Lucas & Lowenberg, 1996). The right hemisphere has an important role in understanding and applying mathematical concepts. Fisher et al. (1991) suggested that this deduction was based on associations between visual-spatial abilities and the understanding of mathematical concepts. The visual-spatial abilities can be determined in picture completion and copying tasks which are important predictors of arithmetic (mathematical) achievement (Belka & Williams, 1979; Sorter & Kulp, 2003).

In summary, it would appear that mathematical ability is affected by visual perceptual skills (see Table 2.4). These visual perceptual skills include, but are not limited to, visual memory, visual sequential memory, visual perception and specifically visual spatial ability (Belka & Williams, 1979; Chinn, 2002; Fisher et al., 1991; Green & Chee, 1997; Hung et al., 1987; Levine, 1991; T. Miles et al., 2000; Schneck, 1996; Simpson, 1987).

Table 2.4

Summary of visual perceptual skills related to mathematics

Author	*Visual perceptual skills related to mathematics*
Green & Chee (1997)	Poor mathematics is associated with poor handwriting, poor organization and poor working memory
Miles, Chinn & Peer (2000)	Mathematics is made up of shape, space, symbols, copying & innumeracy
Chinn (2002)	Mathematics includes visual discrimination, directionality, sequencing, organizational (spatial) & memory
Schneck (1996)	Figure ground was required
Hung, Fisher & Cremack (1987)	Poor visual skills related more to mathematics than to reading & spelling

Note: Summarised by the author from: Chinn, 2002; Green & Chee, 1997; Hung et al., 1987; Miles et al., 2000; Schneck, 1996.

Influence of visual perception on comprehension

Lategan (2002) stated that it was not successful word recognition that allowed children to comprehend what was read, but that meaning was constructed using a variety of sources such as experience and pictures as frames of reference. Others (Belka & Williams, 1979; Green & Chee, 1997), theorised that weaknesses in reading comprehension may be caused by memory problems, where the child is unable to remember what was read at the beginning of the paragraph by the time they reach the end of the paragraph, thus failing to acquire meaning from the printed information. They concluded that visual-motor and visual-perceptual (visual sequential memory and visual discrimination) abilities were important predictors of reading comprehension scores.

Loikith (1997) postulated that visual imagery is an important skill in reading comprehension. This was supported by top-down or whole language supporters who believe that children will analyse the words once they discover that the text does not make sense (Truch, 1991). In contrast, Rynearson (1999) found that beginning readers did not rely on context to create meaning from text, but rather relied on the decoding of the words using the letter-sound correspondence. This view is relevant in the current research where the decoding of words will result in accurate identification of reversed letters or transverse letters that change the meaning of the word or the context of the word. In summary, comprehension is viewed as the effective use of visual perception (analysis and decoding) and personal frames of reference in order to derive meaning from a passage that is being read (Belka & Williams, 1979; Green & Chee, 1997; Lategan, 2002; Rynearson, 1999).

Diagnostic Groups and their Impact on Visual Perception

Current research literature is useful in identifying assumptions about visual perceptual development and the influence of visual perception on daily functioning. Visual perception is identified as being symptomatic in certain diagnostic groups. A number of these groups will be considered in order to provide an overview of the assumptions of the influence of the nervous system on visual perception. The following diagnostic groups will be discussed: learning difficulty and visual disorders.

Learning Difficulty

The terms learning difficulty, learning disability, specific learning disorder, dyslexia, minimal brain dysfunction syndrome, psycho-neurological learning disorders, perceptual handicap and non-verbal learning disorders may be considered to be synonymous due to the similarities in definition (Kirk et al., 2000). In this research, learning difficulty or learning disability will be used to describe the two major clusters of learning difficulty: (1) reading disability, also known as dyslexia and (2) arithmetic (mathematics) disability, which is sometimes known as non-verbal learning disability, developmental output failure, writing-arithmetic disability or visual-spatial disability (Siegel, 1999). Developmental disorders in the areas of reading, written expression and mathematics are classified under learning disorders in the *Diagnostic and Statistical Manual of Mental Disorders* (2000-TR; Thomas, 2000).

The term 'specific learning disability' has been used to describe children who have a discrepancy between their tested intelligence and their performance in certain specific learning areas (Gordon, Lewandowski, & Keiser, 1999; Green & Chee, 1997; Grove & Haupfleisch, 1978; Siegel, 1999; Thomas, 2000). The most frequent of these discrepancies are in reading, spelling, writing, language and mathematics. Hung, Fisher and Cermak (1987) related visual perceptual deficits or low visual perceptual abilities to a significantly higher verbal than performance score on the Wechsler Intellectual Profile (Hung et al., 1987), while Rosner (1993) stated that children who are confronted with the task of learning to read, write, spell and do arithmetic, under standard school conditions, before they have developed the basic (visual and auditory) analysis and language skills will have learning difficulties. In addition, when children have difficulty concentrating, they lack the ability to interpret what they see (poor visual perception) even when they have normal eyesight. The basic visual perceptual skills required for reading become challenging as these children often memorise written materials until the task is too complex to memorise.

Silver (2001) identifies the following four steps in the learning process: (1) input (visual, auditory and the perception of this input), (2) integration (sequencing and abstraction), (3) memory and (4) output (language or written response). Difficulty in any one or more of these areas may result in a learning disability (Silver, 2001). Furthermore, learning disability is identified in that it: (1) is marked by heterogeneity, (2) is probably the result of central nervous system dysfunction, (3) involves psychological process disorders, (4) is associated with underachievement, that interferes selectively with academic functioning, (5) can manifest in spoken language, academic or thinking disorders, (6) occurs across the lifespan and (7) is not the result of other medical conditions (Kavale & Forness, 2002; Kirk et al., 2000).

Children with attention and learning difficulties may have reading or mathematical difficulties due to poor visual attention, memory and perception (Barkley, 2005; Serfontein, 1990). Many of these children have difficulty establishing left to right progression in writing and spatial difficulties are reflected in their writing and reading. Visual perceptual skills identified as specific difficulties for children with learning and attention difficulties are visual reception (the ability to gain meaning from visual symbols), visual discrimination, visual memory, visual spatial difficulties and left-right orientation (Barkley, 2005; Serfontein, 1990) which contribute to the resulting academic difficulties (Benn, Venter, Aucamp, & Benn, 2000; Murray-Slutsky & Paris, 2000).

Hoffman and Rouse (1987), and Erhardt and Duckman (2005), agreed that visual information processing problems of bilateral integration, directionality, visual discrimination and visual motor integration were prevalent in more than 40% of children with learning disabilities. It would thus appear that researchers agree theoretically that a learning disability displays itself in a heterogeneous group of children who under-perform in academic areas, such as reading, spelling, writing and mathematics. The skills required for learning to read, write, spell and do computations are identified by developmental theorists as whole-picture processing and perceptual motor development which occurs before logic and linear processing. Therefore, it can be argued that a child who is experiencing difficulty with academic tasks may have underlying perceptual difficulties. This argument that learning disabilities and perceptual dysfunction are closely linked will be adopted as the structural model for the approach used in this study (see Chapter Four, Theoretical Framework).

Visual Disorders

Dysfunction of the visual pathways may produce visual field defects. Brainstem, temporal, parietal or occipital lobe dysfunction may result in visual perceptual omissions, distortions, preservations, rotations, misplacements, reversals or errors in judgement of size (Gaddes, 1980). Lesions of the secondary visual area result in a loss of ability to recognise objects seen, as the memories of past visual experiences stored in this area of the cortex are deleted (Snell, 2001). Researchers postulate that visual problems that remain undetected, may result in invalid visual perceptual assessment results and inaccurate clinical reasoning and that visual deficits may affect long-term vision outcomes and educational achievement (Goldstand et al., 2005). However, there is insufficient data regarding the possible effect that visual deficits may have on higher-level visual-information processing assessments (De Haan & Newcombe, 1992; Goldstand et al., 2005; Siatkowski, Zimmer, & Rosenberg, 1990).

In an overview of studies relating vision to learning, Scheiman (1997) found that there is a relationship between refractive status and binocular vision and reading (Grisham & Simons, 1986). Children with visual problems were found to perform significantly poorer on educational tests that other children (O'Grady, 1984). Reading achievement was significantly related to visual perceptual performance (Groffman, 1994; Kavale, 1982).

Summary of Visual Perception

Visual perception begins developing at birth and continues to develop into the teen years, however, the majority of researchers report that the major period of visual perceptual development is from four to seven or eight years of age (Cherry et al., 1989; Edwards, 1987b; Frostig & Horne, 1964; Hanneford, 1995). Towards the end of this period, children begin school and have to learn to read, write, and perform mathematic calculations (Frostig & Horne, 1964; Johnson & Myklebust, 1978; Kirk et al., 2000; Kranowitz, 1998; Kulp, 1999). Visual perceptual difficulties are symptoms of a number of diagnoses and as a result influence the clinical reasoning of occupational therapists working with children who have visual perceptual difficulties. Consideration will be given to the theoretical models and frames of reference relating to visual perception in order to identify the guidelines for working with children who have visual perceptual difficulties.

In the next chapter, Part 2 of the Literature Review, theoretical models used as frames of reference and occupational performance of visual perception are analysed and explained, and the model developed for the present study is set out. Assessments used in the measurement of visual perception and letter and number reversals are compared and evaluated. This will lead into the reasoning for development of the current measure (Richmond Reversal Rating) as an instrument of measurement of visual perception in young students.

CHAPTER THREE

LITERATURE REVIEW (Part 2)

MAJOR THEORETICAL MODELS AND EVALUATION OF VISUAL PERCEPTUAL REVERSAL TESTS

This chapter discusses the theoretical frameworks that guide assessment and intervention of visual perception related to letter and number reversal. Models informing the theory of visual perception, which guide the clinical reasoning of occupational therapists, are generally divided into five categories which include approaches in the areas of: (1) neurological development; (2) motor control; (3) perceptual processing; (4) sensory integration; and (5) visual development. These are briefly outlined and explained in relation to the present study. Theoretical models of letter and number reversals, an important aspect of the current research study, are outlined. Following this, there is a critique of current tests of letter and number reversals. All of these used True Score Theory measurement which can only produce a non-linear scale at best, and none have been standardised using modern measurement models like Rasch Measurement. Some problems with the current measures are explained.

Neurological Developmental Approaches

The neurological developmental approach to visual perception is based on the development (neurological maturation) of the individual, behavioural (environmental influences) and cognitive (mental process of constructing knowledge from interaction with the environment) components (Erhardt & Duckman, 2005). This approach considers learning as an interactive process that occurs through interaction of genetic and environmental variables as well as feedback and practice. The approach allows sequenced activities in preparation for functional tasks. Important features include a tendency towards increased organisational complexity, modification of activity as a result of experience as growth and maturation is acquired by interaction with, and exposure to, the environment and a craving for purpose and variability (Erhardt & Duckman, 2005; Mandich & Cronin, 2005).

Earlier neurological developmental approaches (Getman, 1962; Getman, Kane, Halgren, & McKee, 1964) emphasised a relationship of intellectual development to the maturity of visual perception, which was based on the principles that: (1) educational success depends on visual adequacy where academic performance depends heavily on form and symbol recognition and interpretation; (2) direct experience enhances perceptual development as there are perceptual skills which can be developed and trained; (3) the child learns to perceive and learns to learn because the development of perceptual skills is related to the levels of coordination of the body parts and systems for developing perception of forms and symbols; and, (4) perceptual success follows a logical, systematic sequence of development, thus the child who has developed perceptual skills is free to profit from instruction and learn independently. Each of these has a strong visual emphasis (Getman, 1962; Getman et al., 1964; Myers & Hammill, 1982). Earlier, Frostig (Frostig & Horne, 1964) also recognised that perceptual adequacy could be fundamental to academic success, and emphasised the development of visual perceptual skills rather than remediation of reading, spelling and writing. Frostig maintained that most learning occurred through the visual channel (Frostig & Horne, 1964).

Hierarchical developmental model

A hierarchical model for evaluation of visual perception was proposed by Warren (1993) and based on the hierarchy of perceptual skill levels that interact and subserve one another. The foundation skills in the model are the visual fields, visual acuity and visual oculomotor function, which are followed by intermediate skills of visual attention and scanning, and the higher level skills of pattern recognition, visual memory, and visual cognition. This model focuses on the underlying cause of deficiency, while identifying the critical skills needed for visual perceptual adaptation as it suggests that higher level visual perceptual skills are dependant on integration of the lower level visual skills (Warren, 1993).

Neuro-developmental approach

The rationale for neuro-developmental treatment and prevention of reading and language retardation was based on neurological organization (Delacato, 1959, 1963, 1966; Dutton, 1998; Erhardt & Duckman, 2005; Myers & Hammill, 1982). It is believed that neurological development follows the sequential continuum of man's evolutionary development and failure to do so will result in the exhibition of problems with mobility and/or communication (Myers & Hammill, 1982, p. 335). This approach suggests that the development of the human brain begins before birth and ends around eight years of age, when the child has developed cortical hemisphere dominance (Myers & Hammill, 1982), and children who have problems in language almost always have incomplete attainment of cortical dominance (Delacato, 1966; Myers & Hammill, 1982). This theory emphasises the importance of neurological organization and maturation for development of normal movement as a prerequisite to experience and functional participation (Delacato, 1959, 1963, 1966; Dutton, 1998; Erhardt & Duckman, 2005).

Motor Control Approaches

Mechanistic learning models are based on information processing and the perception, conception, storage, manipulation, transformation and retrieval of information (Erhardt & Duckman, 2005; Mandich & Cronin, 2005). Motor activity is guided and organised by the sensory systems, and therefore, the coordination of motor activity and perception (perceptual-motor-integration) for motor planning depends on the processing of sensory and motor feedback. This process includes kinaesthetic information processing (sensory component) and programming processing (motor component) which concerns spatial boundaries, temporal aspects and the amount of force needed to overcome gravity and resistance (Erhardt & Duckman, 2005).

Motor Learning

Motor learning and planning is the ability to attain a goal and involves the process of choosing a starting point, direction and speed, time to change direction and place to change direction. Motor skill acquisition involves eye-hand coordination and requires complex and discrete movements. Feedback, facilitation and practice are important aspects of this theory where motor learning produces permanent change in behaviour (Erhardt & Duckman, 2005; Giuffrida, 1998). In addition, motor learning is related to brain organisation and emphasises the significance of motor processes to language, reading, and thinking (Cratty, 1979; Myers & Hammill, 1982). Learning movement is viewed as one of the important components from which the child's personality emerged, but not the central core from which all social, intellectual, perceptual and academic skills emerged. Academic operations such as reading consist of numerous sub-processes, which may or may not be translated to movement patterns (Cratty, 1979; Myers & Hammill, 1982). This theory relates to the current study only with regards to visual scanning of a page and the expected motor response of pointing or marking a response.

Multi-context Approach

A multi-context approach is compatible with motor learning theory. Performance is facilitated by using a systematic variation of task parameters to encourage variability and practice as well as a system of verbal cueing (Lesensky & Kaplan, 2000). Multi-context theories are holistic and task-oriented in nature and follow a hierarchy of cognitive, associative and automatic developmental sequences, with task-oriented behaviour being a result of interaction of many body systems as well as between the person and the environment (Erhardt & Duckman, 2005).

Perceptocognitive Motor Theory

Barsch (Barsch, 1967; Myers & Hammill) formulated a theory of movement that stated a person is a moving being within a spatial world and develops in a sequential fashion. According to this theory, the processing of information occurred in the "perceptocognitive system" which is comprised of the auditory, visual, kinaesthetic, tactual, olfactory and gustatory senses. In the perceptocognitive theory, twelve dimensions of human learning were derived and divided into three main areas: (1) postural transport orientations, which control the body and movement through space and incorporate spatial awareness; (2) perceptocognitive modes that process information from the tactile, kinaesthetic, auditory and visual modes and (3) degrees of freedom that allow choice and options in learning (Barsch, 1967; Myers & Hammill, 1982). In the current study, the concepts of perceptocognitive theory will be reflected in the processing of visual information and making a choice resulting from previous learning experience.

Visual perceptual motor approach

The perceptual motor approach directs the child to follow a predetermined sequence of activities with the focus of achieving a specific goal. This approach uses cross-modal perception that is demonstrated within the first months of life and contributes to concept development of experiences stored in memory. This information processing in infants is related to later cognitive abilities in memory and speed of processing and thus in visual recognition and learning (Erhardt & Duckman, 2005).

Kephart (1960) described a four-phase hierarchy of perceptual-motor development, which incorporated: (1) posture (the basis of all movement), (2) body image (reference point for external spatial relationships), (3) laterality (awareness of left and right for projection of left/right in space) and (4) directionality (first in relationship of the child to external objects and then external objects to each other). His theory is organized into three stages of learning – 'practical, subjective and objective' – based on four motor generalisations – 'posture and the maintenance of balance', 'contact', 'locomotor' and 'receipt and propulsion' (Kephart, 1960; Myers & Hammill, 1982). According to this perceptual-motor theory (Kephart, 1960), the internal awareness of left and right is necessary to acquire accurate perception of external objects such as letter and word reversals. Therefore, the development of perceptual motor skills is the foundation and prepares the child to generalise higher mental processes for functional tasks such as reading, writing and arithmetic (Erhardt & Duckman, 2005; Myers & Hammill, 1982). These perceptual motor skills were derived from basic skills such as drawing a square, which required the integrity of even more basic skills such as gross motor abilities, eye-hand coordination, laterality, directionality, ocular control, dexterity, temporal-spatial translation and form perception. It is suggested that the remediation of basic skills will be generalised to skills for reading, writing and arithmetic (Kephart, 1960; Myers & Hammill, 1982). In addition, Penso (1992) presented a model of perceptuo-motor function where motor activity (excluding reflexes) requires motor planning or praxis, which is preceded by perception (mental activity). Sensory information is perceived (sense is made of shape, size, colour and relationship of objects to each other and to self) once recognition has taken place in the association area of the cerebral cortex. This model informed the outline of the model developed to guide this study (see Figure 3.1).

Perceptual Processing Functions

Melamed (2000) proposed a taxonomy of perceptual processing functions in an attempt to conceptualise visual perceptual skills. The taxonomy of visual processing functions has four levels of processing: (1) Sensory encoding, involving the detection of the stimulus that incorporates sensory discrimination, sensory attending and sensory organization; (2) Perceptual integration involving processing functions that allow the representation of the organizational characteristics and/or spatial localisation, and incorporate perceptual organization, perceptual relation and spatial patterning; (3) memorial classification and retrieval involving the encoding or retrieval process in memory which incorporates pattern classification (intra-modal and inter-modal) as well as naming (verbal constructs); and (4) cognitive abstraction which occurs where perceptual material is employed in higher-level cognitive functions such as those found in conceptual reasoning and problem solving tasks. Cognitive abstraction occurs by manipulation of verbal constructs, mathematical constructs and perceptual constructs.

Cognitive components

Cognition occurs when the organs of the body receive sensory stimulation, which is translated into information in the brain by means of transducers converting the incoming stimuli into information. Information is represented by discrete (distinct) symbols in the brain. These new symbols are compared to existing symbols, possible outcomes are calculated in context to the situation and the different modules in the brain responsible for different kinds of information then send out possible responses. These responses are translated back to stimuli by output transducers and the body responds accordingly. The process is considered to be cyclical and is not affected by time, but is a dynamic system that does not receive only inputs and return only outputs, but is a constantly changing and evolving system that is continually interacting with the body and surrounding environment (Stone, 2003; van Gelder & Port, 1995).

Martin (2006) outlined a number of theories of visual perceptual processes involving cognition. These theories include: (1) the template theory (recognition comes about when the perceived object is matched to stored memories); (2) prototype theory (category representations are constructed to identify objects; these categories reflect the complexity of understanding of the world); (3) feature theory (detecting distinctive individual features of an object is integral to recognition); and (4) the gestalt theory (perception involves detecting and organising the perceived object to gain understanding of what is seen). Comments on these theories are now given.

Stimulus versus Goal Driven Visual Perceptual Theory

The most common definitions of visual perception consider perception to be stimulus driven, however some authors view visual perception as goal driven (Loikith, 1997). In the stimulus driven approach to perception, processing is considered to be "bottom-up", while goal driven perception is considered to be a "top-down" processing. Stimulus driven perception is identified as being stimulated by an object in the visual field (Loikith, 1997). The image is then transferred to the receptor centres where image processing takes place using selective attention. As the perceptual processing occurs, higher-level cognitive function is stimulated. In contrast, goal driven perception is stimulated by the demands of a task or goal. Knowledge or expectations which exist drive the formation of strategies and procedures to allocate attention and command the ocular motor control centres. In the goal driven approach, perception may occur without actual vision such as when a person mentally plans the arrangement of furniture in a room or imagines the shape of a letter before writing it (Loikith, 1997). A definition of visual perception that encompasses both the stimulus and goal driven approaches, states that: "visual perception is the point at which an individual's knowledge meets environmental opportunities" (Loikith, 1997, p. 199).

Three components of visual perception were identified in the goal versus stimulus driven theory. These components include: (1) memory, which is the individual's entire or total knowledge base, with short-term memory being a very small portion of the base that is currently active; (2) attention, seen as the point at which cognitive action is happening in the environment; and (3) encoding which is the process of placing knowledge into memory. Thus, the point of perception is a very limited, active cognitive effort that simultaneously includes attention to the visual field and memories related to the stimulus (Loikith, 1997).

A conceptual framework of visual task analysis

The conceptual framework describes the process for visual task analysis and synthesis. Activity analysis is the process of examining an activity to distinguish its component parts, while activity synthesis as the process of combining component parts of the environment in order to design an activity suitable for evaluation or intervention (Tsurumi & Todd, 1997, p. 369). The term "visual information processing" is used in this framework to refer to all the cognitive skills used for extracting visual information from the environment about objects; representations of objects, space and events; or symbols, and then organising and integrating this information together with other sensory modalities, previous experiences and higher cognitive functions to make sense of the information (Tsurumi & Todd, 1997). Thus, the term visual information processing is used for the same skill that had been described as visual perception, visual perceptual-motor and visual processing by other authors (Gibson, 1969).

In this framework, 'objects' are three-dimensional forms, which are interpreted by using three processes: (1) visual cognition (differentiating the object from the background and organising the visual field with respect to the arrangement and relative location); (2) visual matching (abstraction of the distinguishing features); and (3) visual categorisation (abstraction of the invariant properties and relationships – size, shape and light constancy). These processes are all supported by visual attention and memory and conform to the principles of proximity, similarity, continuation, common fate, closure and symmetry (Tsurumi & Todd, 1997). In the 'space' category, objects are figures on a spatial background. Spatial features are identified, recognised and categorised as objects, with language and memory as the supporting process, while distance and depth are judged using retinal cues (innate skill) and naming of the distance and depth is achieved by using a learned skill of language symbols (Tsurumi & Todd, 1997).

Participation in events, or happenings over time, provides the foundation for the development of concepts of object permanence and causality. Tsurumi and Todd (1997) emphasised that much of the visual stimulation of daily life is from events and involves the interplay of persons with objects and space over time. Representations of objects, space and events occurs when the three-dimensional reality is represented in two-dimensions such as in drawings or photographs. Visual information analysis as it applies to objects can be applied to analysis of representations, such as reading and writing letters and numbers (Tsurumi & Todd, 1997).

A major source of visual stimulation comes in the form of symbols and codes for example, written language, mathematical notation and sign language. According to Tsurumi and Todd (1997), symbols require a mental process of association, thus in reading the meaning of a word has to be known and must be associated with the memory of the corresponding object. Information given by symbols is generally sequential, and in the written language the sequence itself has a particular structure and rules. The structure and content of the symbol system must be detected, recognised and remembered in order to discriminate one symbol from another in the same way as with objects, space, events and representations, however, when using symbols, positional differentiation becomes a distinguishing feature, which changes the identification of the symbol (Tsurumi & Todd, 1997).

Sensory Integration Theory related to Visual Perception

Sensory integration theory investigates the way that sensory processing and motor planning influenced daily life function and learning (Ayres, 1978; Bundy, Lane, Fisher, & Murray, 2002). The theory is used to explain the relationship between the brain and behaviour and explains why individuals respond in a certain way to sensory input from the body or the environment and how it affects behaviour in order to make successful adaptive responses. The five main senses are: tactile, auditory, visual, gustatory and olfactory, with two other powerful senses: vestibular (movement and balance sense) and proprioception (joint/muscle sense) contributing to the input (DiMatties & Sammons, 2003). Four fundamental sensory systems (touch, proprioception, vestibular function and vision) are identified that contribute to perception preceding motor planning and motor execution (Ayres, 1974; Penso, 1992) and provide a crucial foundation for later more complex learning and behaviour (Illinois Service Resouce Center, 2003). The basic tenants of sensory integration are: (1) sensory input is seen as critical for brain function; (2) the central nervous system is plastic; (3) sensory integration occurs along a predictable developmental sequence; (4) the central nervous system is an integrated whole organised in a hierarchical interactive system; (5) integration of sensory input occurs in the reticular formation and influences the rest of the brain; (6) sensory integration attempts to restructure the development where the normal progression of development has been disrupted; (7) sensory integration therapy promotes an adaptive response to sensory input; and (8) children have an inner drive to integrate information (Baloueff, 1998; Bundy et al., 2002; Shaw, 2002).

Sensory integration is said to be the basic sensory process that allows visual functions to be effective (Burpee, 1997; Erhardt & Duckman, 2005). It is sensory integration that enables the central nervous system to process (organise, synthesise and analyse) the input from the body for functional use. According to Burpee (1997) the sensory-perceptual and sensory-emotional experiences become cognitive constructs used to project how people and things beyond us function and give meaning to the stimuli such as the symbols used in reading and mathematical computations. Sensory integration theory presumes that the person's internalised fine-tuning of their own body size is used as a base in addition to visual-perceptual memories of that internalised body awareness to recognise variations in object size and to differentiate and sequence size in series (Burpee, 1997, p. 97). Secondary to body awareness in visual perceptual development is the function of the visual sensory system (Ayres, 1974; Burpee, 1997).

In the sensory integration theory, the visual-vestibular-proprioceptive triad gives meaning to visual-spatial precepts and visual form and space concepts. The ability to organise visual space to be aware of and understand where things are and their position in relation to each other comes from an awareness of how the body orients and organises itself in space, while the ability to discriminate size and object position and placement is based on body awareness and a sense of the body in space (Burpee, 1997). Sensory integrative disorder is identified as having a profound effect on children's participation in everyday occupations including play, study and family activities (DiMatties & Sammons, 2003).

Vision Theory related to Visual Perception

The role of vision in development originated with early pioneers such as Gesell, Kephardt and Getman (Gesell, Ilg, Ilg, Bullis, & Getman, 1949; Getman, 1962; Kephart, 1960). Gesell's work with optometrists led to a multidisciplinary approach to vision and learning (Erhardt & Duckman, 2005), while Knickerbocker (1980) realised the importance of blending visual function with whole-body performance (Knickerbocker, 1980).

Lower level skills or basic visual functions are the most basic and functional visual skills necessary for the development and management of all visual perception and visual motor activities. In addition, these skills must be intact for the person to receive, process interpret and respond appropriately to input from the environment (Aloisio, 1998). Vision assists in bringing eye-hand coordination to higher skill level, and thus affects functional performance of daily occupations of childhood such as self help skills, using communication devices (for example: computer), work, play, education and handwriting. When vision is compromised due to central nervous system damage or optic insufficiencies, so much effort is required to control oculomotor aspects of reading and writing, that very little energy remains available for cognitive processing (Erhardt & Duckman, 2005). Theoretical models suggest that important cognitive qualities accompany the early visual searchings and scanning of infants, where the infant becomes an active seeker of information rather than a passive receiver (Cratty, 1979). These models also support 'pure' measures of visual perceptual ability, which do not call for a written response to indicate the perceptual interpretation (Cratty, 1979).

Scheiman (1997) (a behavioural optometrist) identified specific difficulties in vision related to occupational therapy that included vision information processing disorders. In processing visual information, some task characteristics that would place a high demand on visual efficiency skills included: (1) attention to small internal details of visual stimuli such as words and pictures; (2) precise ocular motor control; (3) accurate sequential inspection of words or visual stimuli; (4) sustained attention on a visual task; (5) emphasis on speed, accuracy and comprehension; and (6) movement during a visual task. In addition visual information processing skills are in high demand for tasks requiring: decisions about directional orientation or spatial cognition; visual recognition such as symbol and word recognition in language; matching of shapes; visual memory; visualisation and copying of visual stimuli (De Haan & Newcombe, 1992; Peterhans & von der Heydt, 1991; Scheiman, 1997). The tasks involved in the current study include visual discrimination which demands attention to small internal details of visual stimuli such as words and pictures; scanning of a page for the correct or incorrect stimulus where precise ocular motor control is involved; accurate sequential inspection of words or visual stimuli; sustained attention to the visual task for as long as it takes the person to find the stimulus; and comprehension of the task and the words included in the study.

Theoretical Models of Letter and Number Reversals

Laterality and directional perception

According to the model of laterality and directional perception, most children who continue to reverse letters, numbers and words have underlying problems that must be remediated prior to these reversals decreasing. These underlying problems may include under-developed visual perception and poorly integrated vision with cortical function and other sensory stimuli. These problems are compounded as there is no right and left, front and back or up and down in space, but the person projects these directions into objective space. Therefore, it is only after the person understands his/her own position in space and is able to match this to the visual perceptual concepts that letter orientation could be grasped (Ayres, 1978; Kephart, 1960; Lane, 1988).

Interwoven within spatial concepts is the child's laterality. Laterality refers to the internal awareness of the two sides of the body and their difference and does not mean naming left and right and is not synonymous with handedness or dominance (Lane, 1988). Differentiation of the two sides of the body occurs through objective (movement across the midline, for example, from left to right) and subjective (movement to and from the midline) movement while observing differences in sensory sensation, as well as the development of balance and the midline concept (Ayres, 1978; Kephart, 1960; Lane, 1988). Complete understanding of the child's own laterality and midline result in understanding of position in space compared to external objects and is referred to as directionality (Lane, 1988). As children develop their sense of position in space, laterality and directionality, they will develop visual perceptual concepts and two-dimensional spatial concepts that will reflect in letter orientation. Thus, in the current study the level of spatial development in two-dimensional space that a particular child is functioning at will be indicated by the child's ability to identify spatial concepts of letters and numbers printed on a page.

Differentiation theory

Differentiation theory claims that perceptual learning and development occur as children cease to see objects as a whole and develop increased sensitivity to stimuli to which they are exposed, thereby they become better able to distinguish (or differentiate) those variables which identify one object from another (Lane, 1988). Differentiation theory holds that discovery of distinguishing features of letters is a prerequisite of learning to read (Lane, 1988). Letters are identified as a code rather than a picture, thus type/font style is not important, but the way the child scans the letter and sends the code to the brain for identification is critical. In differentiating the distinguishing features, spatial processing normally occurs from the top to the bottom, however, in young children the eye is attracted to the most salient aspects of figures, which may be at the bottom and thus the scanning direction is confused (Lane, 1988). Spontaneous horizontal scanning is from left to right with the starting point at the left, however, if the child's eye is first attracted to the salient feature, then he/she will scan incorrectly, for example, instead of scanning a 'b' as a line followed by a loop, he or she may first be attracted to the loop and scan the letter as a loop followed by a line and hence a 'd' is viewed instead. This leads to confusion between the scanning and distinctive features thus explaining the presence of letter reversals in some children (Lane, 1988).

Grammar of action rule

In preschool age children, there appears to be uniformity in stroke sequence and direction when copying geometric shapes prior to formal teaching (Lane, 1988). These ingrained motor rules are referred to as the 'grammar of action' and dictate that the right-handed child will start at the leftmost, topmost and vertical aspect of the shape (Lane, 1988). If there is an apex the child will start at the top and work left, while horizontal lines are drawn from left to right and vertical lines from top to bottom. Young children also tend to draw with a continuous line. The grammar of action rule proposes that letters requiring rule amendment (those letters that do not start in the left, top vertical aspect of the letter) will most likely be reversed for example 'd' and 'q' (Lane, 1988).

Memory for left and right

According to Lane (1988) remembering left and right is more difficult than remembering up and down and front and back. This may be related to the visual symmetry of the body and many objects in the left/right orientation whereas a young child can see the difference in up/down and back/front visually. Some children exhibit a low priority for learning left/right orientation of certain letters (Lane, 1988), possibly because it is difficult for them to understand or grasp visually.

Cerebellum-vestibular dysfunction

The cerebellum integrates and regulates impulses from the eye, ear and proprioception and controls eye position with respect to the head and body orientation, eye-hand co-ordination and ocular tracking (Lane, 1988). The cerebellum-vestibular theory states that a cerebellum-vestibular dysfunction may cause poor ocular-motor co-ordination which results in the scrambling of the temporal-spatial sequence of visual input at the retinal site. Therefore, the cerebral cortex is unable to interpret the sensory information received. This theory states that letters and words are reversed before they reach the brain due to poor ocular tracking skills. The cerebellum-vestibular dysfunction theory includes: reading problems such as omission and insertion of letters in words; displacement or rotation of letters; poor handwriting skills where letters and words converge; poor balance and gross motor skills and loosing the place when reading. The cause of reversals is seen as poor ocular tracking resulting in scanning the words or letters in the wrong direction (Lane, 1988).

Object consistency

In three-dimensional objects, the orientation of the object does not affect the identification of the object (Lane, 1988). At school, the orientation of two-dimensional objects becomes important when a child is faced with the orientation of letters. The child may be used to the low priority to orientation of objects, which can make it difficult for the child to attend to orientation of letters and numbers and thus reversals occur. In addition, left facing letters ('d' and 'q') are reversed more often than right facing letters. This may be related to the fact that in the English alphanumeric series, right facing letters exceed left facing letters in a ratio of 2:1, thus if a child capitalises on the odds of being correct, they will naturally choose to put the distinctive feature on the right, resulting in the reversal of letters facing the left (Lane, 1988; Lee, 2006).

Visual-perceptual theory

Lee (2006) developed a theory for reversal errors from a historical view of visual-perceptual theory. In this visual-perceptual theory, visual perception is seen as the total process for the reception and cognition of visual stimuli (Zaba, 1984) and requires interaction between the individual and the environment as the individual uses visual attention, visual memory and visual discrimination to interpret the meaning of what is seen (Todd, 1999). In the visual-perceptual theory of reversals (Lee, 2006), visual perceptual skills related to reversals in handwriting are considered to be: position in space (discrimination of reversals and rotations of letters); spatial relations (analysis of forms and patterns in relation to one's own body); visual attention (ability to attend to visual stimuli); visual memory (integrating visual processing information with past experience); and visual discrimination (detection of distinctive features of a visual stimulus and to distinguish whether the stimulus is different or the same as others). Examples of interaction of visual perceptual skills related to reversals concern difficulty with visual attention which can cause problems with spelling and letter formation, while difficulty with visual memory may create problems recalling the shape and formation of letters and numbers (Lee, 2006). Inability to discriminate letters and numbers, or a difficulty with position in space and spatial relations, may result in poor letter formation and letter reversals (Lee, 2006).

In the visual-perceptual theory, a reversal error is an individual letter produced orally or in script in inversion of the lateral direction or producing the letter or number as it would be seen in a mirror. Reversal error in letter order of words and numbers refers to production of letters and numbers backwards or from right to left. Visual perceptual skills are required to prevent reversal errors as visual perception allows the person to distinguish between similar letters like 'b', 'd', 'p' and 'q'. Letter and number production and letter combinations involve visual perceptual skills of letter orientation and letter sequence, as well as the ability to recognise similarities and differences of letters and the ability to memorise them ADDIN EN.CITE (Landy & Burridge, 1999; Lee, 2006).

Functional coordination deficit model

Brendler and Lachmann (2001) used Orton's (1925) concept of developmental dyslexia, or strephosymbolia, to describe a model of letter reversals. Orton (1925) described three typical symptoms of strephosymbolia namely: (1) static reversals (difficulty differentiating letters which are horizontally or vertically symmetrical such as p and q, b and d, p and d); (2) kinetic reversals (tendency to confuse palindromes such as 'was' and 'saw', 'not' and 'ton'; and reading from right to left resulting in reversed paired letters or syllables in a word); and (3) mirror reading and writing (Brendler & Lachmann, 2001; Lachmann & Geyer, 2003). Orton (1925) assumed that the two hemispheres of the brain worked in unison to produce a single impression within the early levels of word processing (visual perceptual and visual recognition) while association with sound and abstract meaning (associative or symbolic level) occurs in the dominant brain hemisphere only (Brendler & Lachmann, 2001). Orton proposed that the engrams of visual information are symmetrical since they were represented in both hemispheres. Anomaly in the pattern of hemisphere dominance would lead to a high level of reversal errors in reading and writing. Most modern cognitive explanations of reading disability are based on the assumption of phonological deficits within the language processing system where letter symbol and letter sound association is deficient and may result in reversal of letters and words (Brendler & Lachmann, 2001; Liberman, Shankweiler, & Orlando, 1971). However, Orton (1928) identified a functional level of reading that is not locatable, but includes the temporal and parietal areas nearest to the visual recognition field and assists with association and symbolism.

Reversals are assumed to be a result of the failure to integrate visual and phonological information represented in memory (Lachmann & Geyer, 2003). Reading is a complex cognitive task incorporating coordination of subsystems such as visual functions (configurational and orthographic analysis) and verbal functions (phonological, semantic and syntactic coding and decoding) and guiding functions such as memory, attention and motor skills. Reading can be hindered by dysfunction of any one or several of these functions, or by poor co-ordination of the functions. This model is multi-causal and is referred to as the 'functional coordination deficit' (Brendler & Lachmann, 2001). According to Brendler and Lachmann (2001), reversals will fall into the subgroup of dysphonetics since they reflect a problem connecting phonological and visual representations. Corballis and Beale (1993) postulate that the automatic generalisation of mirror image replicas of incoming visual data in both hemispheres is part of perception. In reading, the spatial information process must differentiate between the automatically generated symmetrical replicas to guarantee letter and word decoding (Brendler & Lachmann, 2001; Liberman et al., 1971). Lieberman et al. (1971) also emphasised that reversals of letters and reversals of sequence were two different systems.

The processing of letters and words occurs by abstract decoding, as the text is seen as symbols and not objects. Information about letter orientation is required to differentiate between symmetrical letters such as 'b' and 'd'. Visual functions involved in reading must perform an efficient suppression of symmetry-generalised information (Brendler & Lachmann, 2001; Lachmann & Geyer, 2003). Reversals made in reading are thus related to the confusion of symmetrically transformed single letters, although Brendler and Lachmann (2001) claim that reversals are not solely caused by phonological deficits, but are related to an inadequate suppression of the symmetry-generalised information.

In the multi-causal functional coordination disability model reversals are viewed as one possible symptom of a deficit in the coordination of visual and phonological decoding in a sub-group of reading disabled readers (Lachmann & Geyer, 2003). In the multi-causal functional coordination disability model the end product/occupational result is reading ability. Therefore, visual information processing and visual perception involved in this model is of significance to the occupational therapist in a school setting where the school occupation for the child is functional reading and writing skills.

Model of Visual Skills, Visual Perceptual Skills and Visual Motor Skills

The existing models of visual perception informed the development of the Model of Visual Skills, Visual Perceptual Skills and Visual Motor Skills (Figure 3.1) (Richmond, 2008). In this model of visual skills, visual perceptual skills and visual motor skills, input (blue) is an external stimulus (vision, visual skills or other sensory stimulus) or an internal stimulus (thought), with the prerequisite enabling processes of visual attention, visual discrimination and visual memory. Throughput/ integration (orange) consist of non-motor visual perception that enables the person to understand letters, words and numbers in the school environment.

Once understanding of the perceived stimulus occurs, the resultant output (purple) occurs in the form of an action, thought or verbal response. Throughout this process, a feedback loop is active allowing adjustment of the visual or thought input and perception to match requirements of the occupational performance (output such as verbalising the image seen, or understanding the written text).

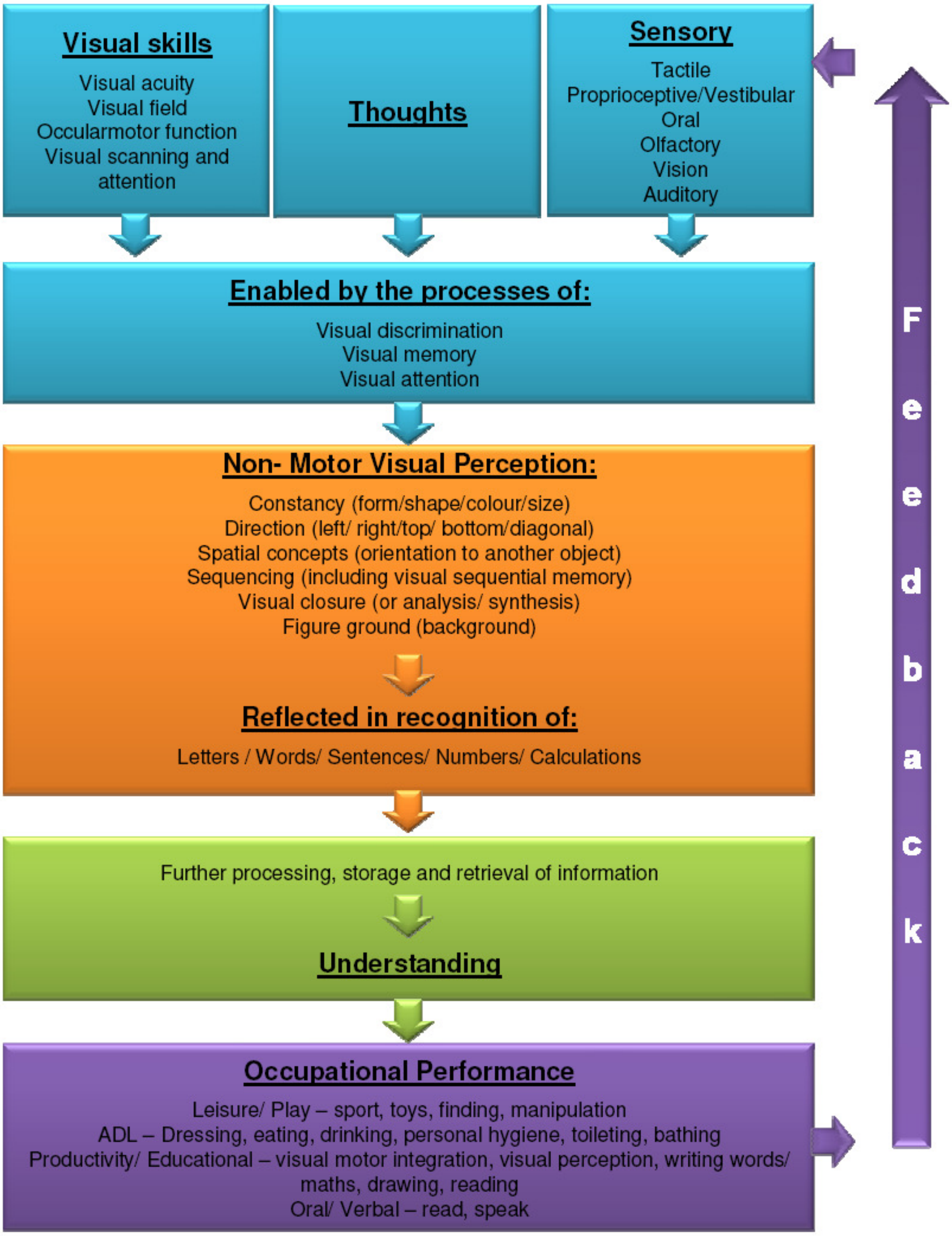


Figure 3.1: Diagrammatic representation of the model of visual skills, visual perceptual skills and visual motor skills developed by Richmond (2008)

Critique of Current Tests of Letter and Number Reversals

Current instruments used to assess visual perceptual aspects of letter and number reversal recognition skills include the *Jordan Left-Right Reversals Test* (JLRRT) (Jordan, 1990), the *Reversal Frequency Test* (RFT) (R. A. Gardner, 1978) and the *Test of Pictures, Forms, Letters, Numbers, Spatial Orientation and Sequencing Skills*

(TPFLNSOSS) (M. F. Gardner, 1991). The goal of these assessments is to discover what knowledge a child brings to the visual task, in other words a child's abilities, strengths and weaknesses (Gregg & Scott, 2000; Loikith, 1997). It is important that the tools used really measure the skills, abilities or traits that they purport to evaluate, so that they have "construct validity" (Bailey, 1991; Clegg, 1982; Cooke, McKenna, Fleming, & Darnel, 2006; Downing, 2003; McDaniel, 1994; Messick, 1995a, 1995b). All these tests use True Score Theory Measurement which can only produce a non-linear scale. None have been used with Rasch measurement to produce a linear uni-dimensional scale. There are, however some reading batteries, sometimes in bilingual mode (Koh, 2008) which are Rasch analysed, but there are very few of these and they are only partially related to the present study.

According to a number of authors (Law, Baum, & Dunn, 2005; Payne, 2002; Richardson, 1996), paediatric occupational therapists are increasingly making use of standardised tests to determine eligibility for therapy services, monitor progress and decide about the type of treatment required. Standardised tests allow for the measurement of the child's performance in a specific area according to the 'norm' or average for a particular age level. However, existing standardised tests in reversals and visual perception are developed using True Score Theory and the measures are non-linear. Reporting of performance on existing tests should therefore be accompanied by a discussion of progress in other areas that may not be measured by standardised testing, due to the subjectivity of these tests to fluctuations in the child, examiner, or environment (Richardson, 1996).

Comparison of Existing Tests of Letter and Number Reversal

The tests of letter and number reversal: *The Jordan Left-Right Reversals Test* (JLRRT), the *Test of Pictures/Forms/Letters/Numbers/Spatial Orientation and Sequencing Skills* (TPFLNSOSS) (M. F. Gardner, 1991) and the *Reversal Frequency Test* (RFT) (R. A. Gardner, 1978) were reviewed according to the purpose of the test, age range, time and method of administration, test structure, standardisation, scoring, reliability, validity, strengths and weaknesses. Summary details of the tests of letter and number reversal perceptual skills are reported in Appendix 1 for The Jordan Left Right Reversal Test; Appendix 2 for The Reversal Frequency Test and Appendix 3 for the Test of Pictures/Forms/ Letters /Numbers/Spatial Orientation & Sequencing Skills.

Purpose of the tests

The JLRRT, RFT and TPFLNSOSS all claim to measure reversals of letters and numbers in order to identify and diagnose those individuals who confuse the orientation and sequence of language symbols. The JLRRT adds reversals of words to its assessment, and claims to have predictive value as a part of a battery of tests to diagnose learning disabilities and as a screening tool for possible neurological dysfunction. In contrast, the TPFLNSOSS includes pictures, forms and sequences of letters and numbers.

Age range

The JLRRT is standardized for children aged five years to adulthood, while the RFT is limited to children from five years to fourteen years eleven months or fifteen years eleven months depending on which part of the test manual is quoted. The TPFLNSOSS is standardised for children aged five years to ten years and eleven months. All these tests were standardised on the population in United States of America.

Time to administer and score

The TPFLNSOSS reportedly takes 15 minutes to administer for younger children and 10 minutes for older children. In the JLRRT, five year old children who have not been in First Grade should have each letter or number visually reproduced by the examiner and the child is required to compare the two letters or numbers. For children aged six through eight years, only Level One is administered. There is no time limit. For ages nine through twelve years, both Level One and Level Two are administered. The full test takes about twenty-five minutes. The RFT has no reported time to administer or score the test, but experience of the author determines that it can be administered in 10 minutes and scored in about five minutes. The JLRRT and the TPFLNSOSS take five to ten minutes to score. The JLRRT can take longer to score initially, as the therapist needs to become accustomed to scoring both the correctly marked reversed characters and the incorrectly marked non-reversed characters.

Method of administration

In the JLRRT, the response format is multiple choice with minimal physical response required. Level Two requires attention to detail and a motivated attitude as carelessness may result in deviant reversal scores. Group testing, although allowed, should therefore be monitored carefully. The RFT is administered individually and requires a written response, as well as reading of individual letters. The child needs to have some concept of letters and numbers in order to complete page one of this test as it relies on memory. The TPFLNSOSS is administered individually and consists of multiple choice type stimuli where pointing is the only motor response required.

Test structure

The JLRRT contains three sections consisting of 27 upper case letters, 27 lower case letters, 14 numbers, 98 words, and 20 sentences, while the TPFLNSOSS contains seven subtests and the RFT exists of three subtests with 24 items in subtest one, 23 pairs and 46 single letters and numbers in subtest two and 20 items in subtest three. The JLRRT only has a total score whereas the TPFLNSOSS has scores for seven subscales as well as a total score, and the RFT has three subscales.

The JLRRT used a panel of judges to select the items that represented a clear cut reversal for Level One. The RFT also claims to use only letters and numbers that could be written in mirror image, but did not use a panel of judges, whereas the TPFLNSOSS used item correlations, and only retained items that showed low biserial correlation to the total score.

Standardisation sample

The revised norms of the JLRRT were based on a sample of over 3000 children with average intelligence (IQ 90 or above). The TPFLNSOSS used a group of 714 children, but did not report the intellectual level of this group in the manual. The RFT produced normative data that was collected on a small group of 254 (115 girls and 139 boys) children with average intelligence. Neither the JLRRT nor the TPFLNSOSS report the gender breakdown of the normative group.

The RFT and the TPFLNSOSS used a sample of children from a limited geographic area (Bergin country, New Jersey and San Francisco Bay respectively), whereas the JLRRT did not report the geographic area. The RFT did not report on ethnicity of the standardization sample. The JLRRT included 10% non-white racial background and the TPFLNSOSS states that no variance was found for ethnicity, but did not provide details of the racial breakdown. All the tests excluded children with special needs from the normative sample. The normative samples were therefore not representative of the general population.

Scoring

In the JLRRT, errors constitute reversed symbols, which were not marked or correct symbols, which were marked as incorrect (Jordan, 1990). The TPFLNSOSS scores only correct responses, while the RFT score is derived only from the number of errors made. Norms are given in developmental age and percentiles for the JLRRT. Norm tables are marked in white areas, indicating adequate scores; a borderline range between two dark lines indicating deviant visual reversals and a grey area indicating more serious visual reversal problems. Two-factor analysis showed significant age and sex factors, and scores are therefore presented in tables relating to male and female. The TPFLNSOSS reports standard scores, percentiles, scale scores and age comparisons. The mean of 100 and standard deviation of 15 was used. The RFT gives standard scores for ages five to fourteen years eleven months, but erroneously presented deciles as percentiles.

Reliability

Due to the nature of the response type (multiple choice) of the JLRRT and the TPFLNSOSS there were no inter-rater tests conducted. The reliability of the JLRRT (1990) was determined by two retest samples. A sample of 99 children was used with a 2 week interval between testing. All Cronbach Alpha reliability coefficients were found to be $\alpha = 0.6 - 0.94$, thus confirming reasonable test reliability. No reliability statistics were reported for the RFT which is a limitation of this instrument. The TPFLNSOSS reported an error of measurement ranging from 3.26 for 5 year olds to 5.60 for eight year olds with a decline in standard error of measurement for older children due to the ceiling effect of the test. The Kuder-Richardson formula was used to determine the reliability of the sum of scaled scores which ranged from 0.85 to 0.95 across all ages.

Validity

No validity data were reported in the RFT manual which is again a notable limitation of this instrument. Gresham and Mealor (2006) identified that the face validity of the RFT is not developmentally correct as 8 year olds made more errors on the Matching subtest than seven year olds and eleven year olds made more errors than eight to nine year olds on the Execution subtest. The JLRRT used only letters, whole words and numbers that were clear reversals to ensure content validity. Concurrent validity was demonstrated by comparing the JLRRT to the Bender Gestalt and Wide Range Achievement Test. Discriminant validity was displayed in a sample of 220 children aged six to twelve years where identified reading disabled children scored significantly lower than normal children. Construct validity was not reported in the manual.

The TPFLNSOSS displayed a content validity of subtest inter-correlation ranging from 0.44 to 0.87; however a bias was found for language and culture. In determining concurrent validity, the TPFLNSOSS was correlated to the JLRRT, the WISC-R, Test of Visual Perceptual Skills, reading and spelling tests, Visual-Motor Integration Test, and Test of Visual Motor Speed for 6 year olds. A moderate correlation was found with the JLRRT, while the other correlations were higher. Discriminant validity was demonstrated in a sample where learning disabled children scored lower than the normative group.

Sensitivity to change

Sensitivity to change within the individual was not reported in any of the tests. The clinical utility for the RFT is suspect as some authors (Gresham & Mealor, 2006) identified that it was difficult to determine whether the RFT does what it purports to do as the technical work is limited. However, one study (Cotter et al., 1987) of 126 learning handicapped children reported poor utility of the JLRRT due to poor agreement with the subjective evaluations of reversals by teachers. A more recent study (Richmond, 2002) of 173 learning disabled children indicated a high level of agreement with teacher ratings and the JLRRT results. Thus clinical utility is controversial for the JLRRT. The TPFLNSOSS on the other hand, claims to display clinical utility for the younger child up to the age of seven or eight years

Summary of Strengths and Weaknesses of Current Measures

All three tests are easy to administer and score. The TPFLNSOSS and the RFT do not require a verbal response or reading/language comprehension, however in Level Two of the JLRRT a degree of reading comprehension is required for successful completion of the test. The TPFLNSOSS combines visual perception with classroom related tasks, while the JLRRT considers reversals of letters, numbers, letters in words as well as whole word reversal. All the tests have gaps in their psychometric evidence, and the RFT does not report any psychometric data and fails to adequately explain the rationale, has a poorly written manual with little detail and some ambiguity and vagueness. The TPFLNSOSS in contrast, reaches a ceiling where there are not enough difficult items for seven, eight and nine year olds and the paper is of a poor quality allowing the print to show through the page resulting in possible confusion to the child. The JLRRT may report an inflated reliability for the older child due to the development of skills. Performance on Level Two is strongly related to reading and comprehension ability. All these tests were analysed using True Score Theory Measurement (not Rasch Measurement) and so only used non-linear scales that were not necessarily uni-dimensional.

In conclusion, the JLRRT appears to be the most psychometrically stable with the largest age range for application. However, the assessments available to assess visual letter and number reversal tendencies all tend to display flaws in their development. These flaws and inconsistencies led to the conclusion that a new assessment of visual letter and number reversal tendencies had to be developed which had linear measures and was psychometrically sound to enable valid inferences to be made. This would ensure that children with letter and number reversal tendencies would be accurately identified and remedial strategies could be instated at an early stage.

The next chapter, Chapter Four, will explain measurement as it pertains to developing a measurement scale which satisfies the criteria of linear scales as well as displaying clinical utility for the teacher or occupational therapist working in a school setting.

CHAPTER FOUR

MEASUREMENT AND VISUAL LETTER AND NUMBER PERCEPTION

This chapter addresses the measurement of visual perception as it is used in this study. The first section will explain measurement in general, while the second section will explain the differences between True Score Theory and Rasch Measurement. This will be followed by specifics of the Simple Logistics Model of Rasch as it is applied to this study and linking it to the RUMM 2020 (Andrich et al., 2005) computer program used to create a uni-dimensional linear scale.

True Score Theory (TST) Measurement

The most widely used measurement model in education is True Score Theory which is based on an assumption that the total (observed) score on a test or questionnaire is the 'true score' plus a random error score. The total score is considered to be 'the measure' and, while it is actually non-linear, it is interpreted as linear. With True Score Theory, almost any unordered set of items will produce a set of data that will fit this measurement model. The current instruments for assessing visual perception and letter and number reversal trends rely on True Score Theory for test construction, and for developing validity and reliability. Testing the instrument provides data for validity, for internal reliability, for item discrimination, and factor analysis. Each item must display an internal criterion correlation to the total test score, or to an external criterion that reflects the trait being measured (Burtner et al., 1997). In this view, the test questions are said to be valid and, if the test data are internally reliable, the test is said to measure correctly what it was designed to measure.

Dimensionality with True Score Theory

True Score Theory relies on factor analysis and inter-item correlations to determine dimensionality of a test. Factor analysis attempts to develop simple patterns of relationships among the variables, by endeavouring to explain how observed variables can be elements of a much smaller number of variables called *factors*. This is achieved by combining two or more variables into one factor. The raw data used in factor analysis is non-linear and the results of the factor analysis are dependant on the sample. This means that two different samples of persons will generate two different sets of factor analysis scores, unlike the Rasch Measurement Model where data are sample independent and the measurements are thus more accurate (Smith, 1996; Waugh & Chapman, 2005; Wright, 1996). This concept is supported by Mitchell (1999), who claims that in True Score Theory, a higher score does not necessarily mean that the person has more ability in that trait than a person scoring a lower score, for example, a person scoring 80% does not necessarily have more ability than a person scoring 76%.

Construct Validity under True Score Theory

Construct validity under True Score Theory is concerned with the accuracy of the measures with evidence presented that support or refute the meaning or interpretation assigned to a test measure (Bailey, 1991; Clegg, 1982; Cook & Beckman, 2006; Cooke et al., 2006b; Downing, 2003b; McDaniel, 1994). Construct validity in True Score Theory determines internal patterns of relationships among test item scores (factor analysis) and external relationships between test scores and other measures test structures (Cooke, McKenna, Fleming, & Darnel, 2006a; Messick, 1995).

Reliability under True Score Theory

In True Score Theory, a study is considered reliable if similar findings are achieved consistently when the study is repeated over time or occasions (Bailey, 1991; Clegg, 1982; Downing, 2004; McDaniel, 1994). The reliability of a measure indicates the amount of random error of measurement as reliability is the ration of true score variance to total score variance (Downing, 2004; McDaniel, 1994) and is a reflection of the characteristics of the test and not a measure of the instrument itself (Downing, 2004). Analysis of variance is used to determine the extent of contribution of each source to the overall error or unreliability. Reliability is usually determined by a Cronbach Alpha Coefficient (Cronbach, 1951) where 0.90 or greater is considered satisfactory.

Item analysis determines the difficulty of an item and its discriminatory power. In order to have two distinctly different yet large enough groups for item analysis, Kelley (Kelley, 1939) demonstrated that the upper and lower 27 percent of the total group was the optimal proportion at the distinct ends of the spectrum of the total group to complete item analysis (McDaniel, 1994). The difficulty index is calculated by dividing the number of people responding correctly for an item in both the upper and lower groups with the total number of people falling into these groups (the proportion of people getting the item right by selecting the correct response) (Catterji, 2003). Item difficulties between 30 and 70 percent are generally acceptable (McDaniel, 1994).

Once the item difficulty is determined, the discrimination index can be obtained by subtracting the number of correct responses in the low group from the number of correct responses in the high group and dividing by the number in one group (McDaniel, 1994). Generally items are more discriminatory as they approach the 50 percent difficulty level. Items with discrimination values of 0.30 and higher indicate adequate discrimination ability (McDaniel, 1994).

Problems with True Score Theory

In True Score Theory, the sample characteristics cannot be separated from the test characteristics, and the error of measurement is assumed to be the same across all individuals. True Score Theory is oriented towards the total test score rather than the items. True Score Theory as it is used in assessment of visual perception and letter and number reversal trends does not ensure that the items are arranged from easy to difficult as it is unable to create linear measures (Wright, 1999). The item difficulties and person measures in True Score Theory are not established on the same scale as in the Rasch Measurement Model and the person measures are thus dependant on the sample and are not the same across all populations. In addition factor analysis used to determine the dimensionality in True Score Theory is not as reliable in detecting uni-dimensionality as the Rasch measures as the error of variance is often too large in the extremes. Almost any test data can fit the True Score Theory measurement model, whereas the Rasch Measurement Model checks for item fit to the Model (Smith, 1996; Waugh & Chapman, 2005; Wright, 1999).

Rasch Measurement

Requirements for measurement

Five criteria have been identified for linear measures in education and social sciences (Andrich, 1989; Wright, 1999). These criteria include: (1) all measures must be linear (along a continuum) with equal levels of difficulty between the item numbers on the scale that represent the same amount of a single trait (uni-dimensionality) being measured; (2) item difficulties must not be dependant on the sample (sample-free); (3) person measures must not be dependant on the items or test (test-free); (4) persons must be able to be measured on items targeted to their abilities, with the remaining items not affecting their measure; and (5) the data must fit the criteria of the measurement model for valid measurement to occur. These criteria should be user friendly and thus easy to apply within the measurement model and software used to analyse the data. Application of these criteria creates a meaningful measure with equal difficulties between the numbers on the scale that represent equal amounts of the trait being measured, while ensuring consistency of the estimates that provide evidence for internal consistency. Thus the data is said to be reliable so that valid inferences may be made from them as opposed to the instrument being valid and reliable (Smith, 2008).

What is Rasch Measurement?

Rasch Measurement is the modern, unified method of viewing validity under one core type: construct validity (Downing, 2003a, 2003b). In the Rasch Measurement Model the probability of a correct response depends on the examinee's underlying ability with regard to the trait, skill or attributes being measured at various proficiency levels and on the item difficulty. This probability is described by an item characteristic curve (ICC) (Downing, 2003a; McDaniel, 1994). The total score on the test usually indicates a proficiency level. The estimate of proficiency for an individual is revised after each response. The total score is the final estimate of the individual's proficiency or ability, which is reached when the standard error of measurement for the last computed proficiency level meets the pre-established criterion (McDaniel, 1994).

Rasch Measurement Models are currently the only known method of creating linear, objective measures in the human sciences which are not sample or item dependant (Bond & Fox, 2007; Waugh, 2006; Wright, 1999). These 'scale-free' measures and 'sample-free' item difficulties are achieved by creating a mathematically objective linear scale with standard units called logits (the log odds of successfully answering the items) (O'Niel, 2005; Waugh, 2006).

The Simple Logistic Model of Rasch

The Simple Logistic Model was developed by the Dane, Georg Rasch (1960/1980/1992). This Rasch model is used to create linear measures when the item responses are dichotomous (two response categories), as in 'right' or 'wrong', 'yes' or 'no' and models the probability of the individual's correct response on each dichotomous item (Andrich, 1988; Bond & Fox, 2007; Maier, 2001; Tennant & Conaghan, 2007; Waugh, 2005) (Ed; Wright, 1999). This Simple Logistic Model (one-parameter model) makes the assumption that the discriminations of all items are equal to one. This allows all model parameters to be estimated simultaneously, incorporating the standard errors of the latent trait estimates into the total variance of the model. Thus people are located on the same linear scale as the items which allow better understanding of the relative distance between performance of people (person location) and the item difficulties (item location) (Bond & Fox, 2007; Tennant & Conaghan, 2007; Waugh, 2005) (Ed; Wright, 1999).

The Simple Logistic Model of Rasch requires items to be designed along an increasing continuum, conceptually ordered by difficulty from easy to difficult for the variable being measured. At the same time, person measures of the variable are conceptualised as being ordered along the continuum from low achievers to high achievers. This implies that persons with low measures will have a high probability of answering the easy items positively, and a low probability of answering the medium and hard items positively, while persons with high measures will have a high probability of answering the easy, medium and hard items positively. There must be agreement between persons about the difficulty of the item, and the item parameter (difficulty) does not change for different persons (Andrich, 1988; Wright, 1999). The equations used to determine these parameters are presented in Table 6.2.

These equations are solved by determining logarithms and applying a conditional probability routine with a computer program such as RUMM (Rasch Uni-dimensional Measurement Models) which provides a comprehensive set of output data to test many aspects of both the conceptual model of the variable, the answering consistency of the response categories, both item and person fit to the measurement model, and targeting (Waugh, 2006).

Table 4.1:

Equations for the Simple Logistic Model of Rasch

Probability	Equation
Probability of answering positively (score 1) for person n	$= \dfrac{e^{(Bn-Di)}}{1 + e^{(Bn-Di)}}$
Probability of answering negatively (score 0) for person n	$= \dfrac{1}{1 + e^{(Bn-Di)}}$

Where:
e = natural logarithm base (e=2.7318)
Bn = parameter representing the measure (ability, attitude, performance) for person n
Di = parameter representing the difficulty for item i

Reliability with Simple Logistic Model of Rasch

The Rasch Measurement Model provides indices which indicate the items are evenly spread across the continuum and whether there are enough items to accurately measure the ability among persons. The person reliability index indicates the order of location of the person on the scale which is replicable in a parallel set of items measuring the same construct (Bond & Fox, 2007; Wright & Masters, 1982). The estimates of the person measures and their standard errors are used in the RUMM program to calculate the Person Separation Index which is similar to the Cronbach Alpha (Andrich & van Schoubroeck, 1989; Cronbach, 1951). The Person Separation Index is constructed from a ratio of the estimated variance (discrepancy) of person measures and the estimated observed variance of person measures. Person reliability requires ability estimates which are well targeted to the items, so that the measures demonstrate a hierarchy of ability.

The item reliability index indicates the repeatability of the item locations along the continuum for any sample, indicating the item difficulty level. The item-person test of fit uses residuals to examine the actual responses and the expected responses as estimated item parameters of the measurement model. These residuals are summed and standardised to approximate a distribution of items with a mean near zero and a standard deviation near one when the data fit the measurement model (Andrich & van Schoubroeck, 1989; Wright & Masters, 1982). Item Characteristic Curves are produced by the RUMM program to examine how well the items differentiate between persons scoring above and below the item locations.

Construct Validity with Rasch

Construct validity focuses on the idea of the items contributing to a measure of a single underlying construct. The Rasch Model infers that the measured behaviours are an expression of that construct. Rasch measurement has been shown to detect uni-dimensionality better than factor analysis in several studies (Smith, 1996; Waugh & Chapman, 2005; Wright, 1996), however, De Soete (1984) claimed that the requirement of uni-dimensionality is equivalent to the requirement of local item independence.

> "*A subject's performance on a specific item is not affected by his or her performance on any other items of the test. Thus, all we need to know to predict a person's performance on a specific item i is (besides the item characteristic) his or her ability parameter. Knowledge of of the subject's performance on any other item is not required. If it would be, then performance on item i would not only depend on the ability parameter, but also in part on some other trait. Consequently, local independence implies uni-dimensionality and vice versa.*" (De Soete, 1984, p. 182)

The item-trait interaction chi-square is one way to check on local independence, where the agreement between the observed value (student response) and the predicted value from the Rasch parameters (predicted item response) to each item for all students with the same ability along the scale is checked. This is the item-trait interaction chi-square where one parameter for each respondent (ability measure) is used with one parameter for each item (the item difficulty).

> "*If the observed and expected values are not significantly different according to this statistic, then there is no significant interaction between the response to the items and the location values of the persons along the trait, as is required according to the model*" (Andrich & van Schoubroeck, 1989, pp. 479-480).

In addition, Andrich (1988) claims that uni-dimensionality is a relative concept, where every human performance, action, or belief is complex and involves a multitude of for example, component abilities, interests and so on. Andrich (1988) further explains that a "uni-dimensional variable is constructed, making a great deal of ingenuity and knowledge of subject matter to establish a variable that is uni-dimensional to a level of precision that is of some practical or theoretical use" (Andrich, 1988, p. 9). A third aspect of uni-dimensional measurement is that "comparisons can be made using their differences. Such differences are differences in degree. Differences that are not differences in degree are said to be differences in kind, and both are important" (Andrich, 1988, p. 9)

The tests of visual perceptual letter and number reversal tendencies were designed so that items in each scale were conceptually ordered by increasing difficulty. In Rasch measurement all the item difficulties are calculated on the same linear scale and so the item difficulties can be compared with their conceptualised order. Thus the agreement of students on the difficulty of the items is determined by the RUMM2020 program to ensure that a linear scale is achieved. When the data fit the model, it is possible to delete the items where there is no agreement, as these items produce 'noise' in the data analysis (Bond & Fox, 2007; Waugh, 2006; Wright, 1999).

The RUMM2020 Computer Program

In this study, the Rasch Uni-dimensional Measurement Model (RUMM2020) (Andrich et al., 2005) was used to analyse the data and create a linear scale for the letter and number reversal recognition measure. Further data analysis with the RUMM computer program included: (1) testing that the response categories were used consistently, (2) testing for dimensionality, (3) Testing for good global Item-Person Fit Statistics, (4) Person Separation Index, (5) testing for good individual item and person residuals, (6) producing Item Characteristic Curves, (7) producing Person Measure/Item Difficulty Map, and (8) testing for construct validity (Andrich et al., 2005; Bond & Fox, 2007).

The RUMM program tests for consistency of use of response categories by calculating threshold values (the odds of 1:1 of answering incorrectly or correctly) between the response categories for each item, and presents this data as a graphical relationship between the linear measure and the probability of answering each response category. An item-trait test-of-fit is calculated as a chi-square with a corresponding probability of fit (Andrich et al., 2005; Bond & Fox, 2007). This determines the interaction between the item responses and the person measures on a variable and shows the collective agreement for all items across persons of different measures along the scale. A uni-dimensional measure is obtained when there is no significant interaction between the item difficulties and person's responses, thereby inferring that a single parameter can be used to describe each person's response to the different item difficulties (Andrich et al., 2005; Bond & Fox, 2007; Waugh, 2006).

Residuals are the differences between the actual responses and the expected responses as estimated from the parameters of the measurement model, determined by the item-person test-of-fit. The standardised sum of these residuals will approximate a distribution with a mean near zero and standard deviation near one, when the data fit a Rasch measurement model (Andrich et al., 2005; Bond & Fox, 2007). The RUMM program calculates a Person Separation Index using the estimates of the person measures and their standard errors that is constructed from a ratio of the estimated true variance and the estimated observed variance among person measures (Andrich & van Schoubroeck, 1989). In addition, Item Characteristic Curves examine how well the items differentiate between persons with measures above and below the item location (Andrich et al., 2005; Bond & Fox, 2007; Waugh, 2006), while the person measure/item difficulty maps indicate how the person measures and item difficulties are distributed along the same variable (measured in logits). The person measure/item difficulty show how well the item difficulties are targeted at the person measures, including which items are too easy or too hard for the persons being measured and whether new items need to be added, or whether there are too many items of similar difficulty (some of which are thus not needed) (Andrich et al., 2005; Bond & Fox, 2007).

Letter and Number Reversal Recognition Scale

Items were developed for the measure using information from the literature according to the theoretical framework (see Figure 3.1) as well as empirical information from observing students at work. From these sources, items were created relating to aspects of visual perception as presented in the model (Fig3.1). An example of this would be the upper case letter J in visual discrimination of upper case letters where the student would be required to distinguish between J , ᒐ, ┘ as a function of visual discrimination according to the description of visual discrimination given in Categories of Visual Perception (Edwards, 1987b; Grove & Haupfleisch, 1978; Todd, 1999; Kranowitz, 1998; Kirk et al., 2000; Levine, 1991). This description related visual discrimination to the ability to differentiate or recognise similarities and differences (distinctive features) in symbols or letters by matching or separating shapes, as well as the ability to differentiate changes in position.

The Victorian Cursive Script was used for the items as this is the font that is taught in the schools in Western Australia. The items in the measure were presented for review to a group of six occupational therapists with at least five years of experience working with school aged students in the area of letter and number reversals. Each therapist was asked to comment on three aspects of each scale, namely:

(1) Does this section adequately sample the content of commonly reversed upper case letters?

(2) Does this section differentiate between children who would naturally reverse these letters and those that would not? And

(3) Does this section provide information that would be useful in intervention of visual perceptual skills influencing letter and number directionality? This input was used to change the measure as described below.

All slants of letters and numbers were removed or minimised as students who tend to reverse letters and numbers do not slant their writing, and the print in books is also not slanted. Throughout the measure, the font size was increased to accommodate the younger student who is accustomed to larger fonts. The individual letters and numbers were also spaced further apart so that students could easily mark the item they chose. There was general consensus that recognising reversed letters in words and reversed numbers in calculations was a good assessment of functional use of letters and numbers and therefore a good scale to maintain in the measure. The scales which targeted figure ground perception by confusing the words and numbers by adding additional lines were removed as the letters in words and numbers in calculations were considered sufficient assessment of figure ground perception. There was no consensus among the occupational therapists about the effectiveness of the reversed words in sentences as a definitive diagnostic tool and this section was thus removed. For the same reason, the section assessing visual closure of incomplete letters and numbers was removed. After these changes, there were eight scales left in the measure, incorporating visual discrimination (three scales), spatial orientation (one scale), sequencing (one scale), form constancy (one scale) and figure ground (two scales).

Item Difficulty/Construct Validity

Linear scales were created for each of the eight measures with the items ranging from easy to difficult within each test. For Visual Discrimination of Upper Case Letters, the letters were categorised according to their symmetry around the vertical axis. Thus a letter such as ‘X’ or ‘T’ which cannot be reversed if rotated on the vertical axis is an easier letter to identify. Letters that have similar shapes but different orientation on the page, such as ‘S’ and ‘Z’ were considered to be the most difficult due to the ease with which they could be confused. Letters that could be reversed because of no symmetry around the vertical axis but did not have similar shaped letters in the opposite orientation such as ‘D’ and ‘F’ were classified as medium difficulty. Letters were presented in the reversed and non-reversed orientation in order to determine when the students found the identification of letters most difficult.

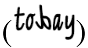
Visual Discrimination of Lower Case Letters item difficulties were categorised using a similar method, with letters that produce a natural flow in writing, such as ‘m’, ‘n’ and ‘r’ considered as the easiest letters to identify in terms of directionality. Letters which had similar shapes around the vertical or horizontal axis were considered the most difficult to identify in the correct or reversed orientation, for example: d, b, p and q. The Modern Victorian Cursive Font was used, which allows the b and p to be open, however, they were still considered to be difficult as clinical experience indicated that students still tend to reverse these letters when applying them to reading and writing tasks. Letters such as f and t were considered more difficult as they could be reversed on the horizontal axis, while letters such as ‘k’, ‘h’ and ‘a’ were considered easy, as they could be rotated on their horizontal axis, but did not have any similar looking letters in the reversed orientation.

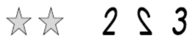
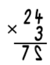
For Visual Discrimination of Numbers the easiest numbers were those that were symmetrical around the vertical axis, such as 1 and 8. Slightly more difficult were the numbers that had a natural flow to the direction of writing, such as 7 and 3. The most difficult numbers were the ones that did not have clues regarding the formation from the flow of the number, such as 4 and 5. Nine and two were also considered to be difficult items due to the similarity to the letter ‘q’ and ‘z’. The slants of the numbers in Victorian Cursive font were exaggerated and the slant was therefore reduced to accommodate this in the test.

Spatial Orientation of Letter and Number Pairs items were developed by including only the most commonly occurring letter and number reversals. Each letter or number pair was categorised as difficult or easy according to the symmetry, similarity to other letters or numbers direction of flow when writing. Thus, the E, and K were considered easier than the S and Z which were classed as very difficult. In the lower case letters, k, m, and n were considered to be the easiest letters to identify in terms of the spatial orientation, while the most difficult were considered to be d, g and r. The easiest number pairs were considered to be the 6 and 4 as there was no symmetry and some degree of natural direction flow. The ‘9’ was considered the most difficult because of its similarity to ‘p’ and ‘q’, thus causing confusion.

In Form Constancy of Letters and Numbers, the easiest items were considered to be those where the reversed letter in Modern Victorian Font were obviously different from all the other letters because of the orientation of all the other letters, for example ‘k’, ‘c’, ‘s’ and ‘f’. When some of the fonts used resulted in a different orientation or shape of the letter such as the a/a, z/z and g/g, there was more space for error and these items were thus considered more difficult for identifying form constancy of reversed letters and number. The numbers used were arranged in numerical order with 4 and 9 considered to be most difficult as the shape of the numbers differed slightly with the different fonts used.

The Letter and Number Sequencing test contained sequences with reversals of orientation in individual letters and numbers within the sequence as well as a range of letter and number sequences with no letter and number reversals but differing sequences which had to be compared. It was considered easier to compare two sequences with two items in each sequence such as, ‘do-do’ and ‘21-12’, where the sequence could change but not the orientation of the individual letters or numbers. It was more difficult to compare a number of sequences with two letters or numbers in each sequence such as ab | ab ba ad ab where the order of the letters and numbers as well as the orientation of the letters and numbers in the sequence could alter. The most difficult items contained sequences with five letters or numbers in each sequence.

The Figure Ground of Letters in Words test was developed using the 200 most often read words (Ramsay, 2007) which were categorised according to grade (year) levels. Thus easy words such as 'one' and 'come' which are learned in pre-primary were considered to be easiest. Words such as 'four', 'that', and 'they' were considered easier, while difficult words included 'because', 'right' and 'upon'. The most difficult words according to the year level where they are most often read were words such as 'today', and 'bring'. The difficulty of the letters in words items was also categorised according to the letter which was reversed as well as the position of the letter within the word. Thus, a reversed e at the end of a word () was easier to identify than a reversed d within a word (), which was considered most difficult.

In Figure Ground of Numbers in Calculations, the year level was taken into account and the easiest items were developed for Pre-primary level such as identifying the correct number from a selection of numbers, such as . The easier items included calculations set out in a horizontal line and contained calculations involving single numbers and double numbers below 30. These calculations only involved the plus and minus sign in the calculation. The students were expected to identify the numbers that were reversed and did not have to calculate answers as these were provided. The more difficult items were calculations presented in the vertical plane with numbers up to 99 and included the times and divide signs, while the most difficult items were calculations presented in the vertical plane including all the calculation signs, such as: .

The next chapter (Chapter Five) explains the methodology of the present study. This will include ethics, demographics or the sample population and the details of the test development.

CHAPTER FIVE

RESEARCH DESIGN AND METHODOLOGY

This chapter explains the methodology and research design used in the present study in which eight linear uni-dimensional scales were created. Administrative and ethical approvals used in this study are first outlined. The planning and design of the study followed six stages: (1) Item and test development; (2) Test item content and definitions; (3) Item refinement and test assembly; (4) Data collection and data entry; (5) Data analysis; and (6) Reporting Rasch analysis results.

Ethical Considerations and Administrative Approval

In order to obtain approval to conduct research involving human subjects, the ethical procedures had to be in accordance with officially sanctioned procedures. Ethics clearance and formal permission to conduct the research was granted by Edith Cowan University Ethical clearance number: 3054 RICHMOND for the period 9th October 2008 to 31st December 2011 (Appendix 4). A letter of explanation was developed for the parents (Appendix 5) as well as the school principals. This letter detailed the nature of the study as well as the student, school and parental involvement and the measures undertaken to ensure anonymity of the students. The letter was accompanied by a parental consent and demographics form (Appendix 6). The parents were requested to complete and sign the consent form indicating their willingness for their child to participate. The voluntary nature of the student's participation in the study was outlined in the consent form. At no point was the student disadvantaged due to not taking part in the research project, as no changes to the routine running of the school programme were introduced.

The present study was conducted on the school premises during school hours and the ethical clearance from The Western Australian Department of Education (Appendix 7), as well as the Catholic School Council (Appendix 8) was also obtained. In addition the Principal of each school was required to sign a consent form to allow the researcher access to the school property. The researcher also obtained a "Working with Children Check" as per the legal requirements of any person working with students under the age of 18 years in Australia.

Research Design

The design of the present study utilised a series of stages as recommended by Downing and Haladyna (2006) to develop the measurement tool (eight tests), collect the data and analyse the data. Each stage is briefly outlined.

Stage One involved planning the test development, format and desired interpretations. During this stage, a model of visual perception was generated to guide the test development.

In Stage Two, the content definitions and specifications were developed. This involved generating tests as a sample of the domain and operational definitions based on expert opinion, input from paediatric occupational therapy clinicians, through review of relevant literature, analysis of academic tasks children complete in academic contexts and content analysis of existing tests.

Stage Three involved the item development and test assembly, including designing and creating test forms as well as selecting items for specified test forms and subscales of test forms (Downing & Haladyna, 2006). Subsequently a research version of the eight tests and scoring criteria were generated that adhered to evidence-based principles of modern measurement in education. A preliminary working version of the manual outlining the eight tests and the administration and scoring of these tests was also developed.

Stage Four involved the test production, scoring and administration. At this stage, the Rasch Measurement Model (Rasch, 1992) guided the test development and data analysis. Rasch measurement was used because it is the only educational measurement model that produces a linear scale (Andrich, 1988; Wright, 1996, 1999). Emphasis was placed on quality control, item analysis and fit to the measurement model.

The final stage involved reporting of the results according to the Rasch Uni-Dimensional Measurement Model computer program (RUMM2020) (Andrich et al., 2005) and included the appropriate item analysis evidence listed in the 1999 edition of *Standards for Educational and Psychological Assessment (American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, 1999)* and the Journal of Applied Measurement website (Smith, 2008). Evidence of validity was derived from: (1) content validity which was derived from the literature, opinion of experts in the field and reviewing of the existing test materials; (2) evidence based on logical and consistent item scoring with item difficulties similar to those conceptualised which involved a component of construct validity; and (3) evidence based on scale reliability gained from conformity to the Rasch Measurement Model.

Item and Test Development

Stage One (Planning)

Items for the measurement instrument of letter and number reversal recognition skills were generated according to the definitions of the visual perceptual constructs identified for assessment. Existing theories of visual perception and letter/number reversal recognition skills, tests of visual perceptual skills and letter/number reversal recognition skills, expert opinion and literature review results were used to shape the items generated for this instrument. The visual perceptual model adopted for the study was used to further guide the items generated.

The tests were designed using a paper base format where the response was marked manually by the student or by the researcher according to the student's direction using a standard pencil or pen. There were eight tests based on letters and numbers incorporating: correct orientation, reversed orientation, correct sequences and incorrect sequences. In keeping with the current visual perceptual literature, the following eight tests were used: (i) Visual Discrimination of Upper Case Letters (18 items), (ii) Visual Discrimination of Lower Case Letters (31 items), (iii) Visual Discrimination of Numbers (14 items), (iv) Spatial Orientation of Letter and Number Pairs (27 items), (v) Letter and Number Sequences (36 items), (vi) Form Constancy of Letters and Numbers (18 items), (vii) Figure Ground Letters in Words (34 items), and (viii) Figure Ground Numbers in Calculations (13 items). Letters and numbers were printed in the Victorian Modern Cursive script as this was the script taught to students by schools in Western Australia.

Currently available assessments of visual perception and letter and number reversal recognition skills tests fail to make adequate connections with daily academic performance demands placed on children in school environments. The current tests have all been analysed qualitatively or with True Score Theory that only creates a non-linear scale. A model of visual perception that incorporated letter/number reversal recognition skills was proposed in Chapter Three. This provided the basis for the theoretical constructs that were formulated and evaluated within a testing context. The tests were designed to identify students with visual perceptual difficulties influencing their academic occupational performance related to letter/number reversal recognition skills. Specific constructs of non-motor visual perception and abstract visual perceptual reasoning identified in the model were operationalized in the test subscales of visual discrimination, form constancy, visual spatial orientation, visual figure ground, and visual sequencing in order to formally evaluate construct validity context. Specific questions posed to operationalize the constructs included: (1) do the items in each test reflect the non-motor and abstract visual perceptual reasoning; (2) are the items representative of mirror images and/or order sequences; and (3) do the items fairly represent the element of the construct being assessed?

Stage Two (Test Item Content and Definitions)

A literature search of Medline, CINAHL, PsychInfo, ERIC, OT Seeker, Buros mental measurements yearbooks, Health and Psychological Instruments (HAPI) and current similar assessments was conducted with the following key words: visual perceptual assessment, letter reversals, number reversals, validity, reliability, test construction, visual perception, visual discrimination, visual form constancy, visual spatial relations, position in space, visual figure-ground, visual closure, visual memory, visual sequential memory, visual disorders, learning difficulties, acquired brain disorder, cerebral palsy, autism, attention deficit hyperactivity disorder, sensory integration and genetic disorders. A review of the current tests was completed to identify weaknesses, strengths, omissions, scoring format and possible items for inclusion. Experts in the field of visual perception and learning as well as paediatric occupational therapists who have five or more years of clinical experience were consulted for input.

A pool of items was generated by the author for the present study. The constructs and elements were evaluated and investigated within an occupational performance framework by using letters/numbers and words in line with academic expectations of students in academic settings ranging from the first year at primary school (Pre-primary) to the fourth year at primary school (Year Three).

Construct Operational Definitions

Construct operational definitions appear in the manual of the developed test. The definitions are specifically designed to fit the model used in this study, but are drawn from frequently used visual perceptual and letter/number reversal recognition theories ([AOTA], 2002; Adams & Sheslow, 1995; Beery, 1989, 1997; Beery & Beery, 2004; Brown, Rodger, & Davis, 2003; Bunker & Widaman, 2001; Burns & Snow, 2006; Canivez & King, 2005; Colarusso & Hammill, 2003; Coster, 1998; Coster, Deeney, Haltiwanger, & Haley, 1998; Frostig et al., 1966; M. F. Gardner, 1991, 1996; R. A. Gardner, 1978; Gresham & Mealor, 2006; Hammill et al., 1993; Jordan, 1990; Miller, 1982).

Letter, number or word reversal is the mirror image or inverted mirror image of the item, for example, "*p*" can be represented as q, P, b, or d and the word "saw" as "was". Discrimination of letters, numbers and words relates to the form, orientation, sequencing and figure ground of letters, numbers and words that contribute to the perception of these symbols and will thus be assessed in conjunction to these constructs; for example, in determining if a child can discriminate between a '*b*' and a '*d*' one is testing their spatial orientation and form constancy of the letter. Form constancy of letters, numbers and words relates to the ability to recognise letters, numbers and words regardless of the script they are written or printed in (a, ***a***, a, a, A). Spatial orientation of letters, numbers and words is the directionality of the symbols, position on the page or in the task and their positioning within the word or mathematical problem (e.g., find the b in: d, b, p, q; or find the 54 in: 45 + 9 = 54). Figure ground of letters, numbers and words is the ability to identify a reversed letter or number within a set of other letters, numbers and words, or to identify a reversed letter, number or word in a decorative presentation (e.g., find 'a' in 'A man fell over' or '*rain came falling down*'). Sequencing of letters, numbers and words is the position within a group of letters, numbers or words (e.g., coat – caot, taoc; 574 – 547, 457, 475, 745, 754; the dog jumps – the jumps dog). Potential test items were derived from a variety of sources including experts in the field, theoretical and research literature as well as existing instruments of assessment.

Data collection system

Each student identified for participation in the research was assessed by the researcher during normal school hours on the school premises. Students aged five and six years were assessed in pairs, while the older students were assessed in groups of four to six. The objective of the study was explained to the participants prior to the testing being carried out, including the reason for testing and the importance of the student's participation for other students who may be having difficulty. All students were required to attempt all items within a single assessment which was less than 30 minutes for year Two and Year Three students and 45 minutes for the younger students. Scoring was carried out by the researcher, as all items were dichotomous with the response either being correct or incorrect and rater reliability was thus not required.

The results of the students with clinical diagnoses such as learning difficulties and neurological disorders were included in order to evaluate the sensitivity and discriminatory ability of the assessment. An attempt was made to match the sample group to the Western Australian census figures for gender, ethnicity, educational level, socio-economic status and intellectual levels by including private and public schools in a variety of economic suburbs. However, this was influenced by parental consent in the participating schools. An attempt was made to obtain a cross section of children from state funded schools and independent schools of Western Australia (but no Catholic schools participated in the data collection phase because none of the principals approached to participate in the study consented to the data collection in their schools).

The students' names were only used on the assessment to identify the background information regarding date of birth, gender, school attended, ethnicity and geographical location. All forms were de-identified once a number was assigned to the students' forms and the score data was entered on the computer. The information used for this research was filed in a locked cabinet according to the Edith Cowan University policy and will remain securely stored for a period of five years to ensure confidentiality and privacy of the participants. Data were entered into a database that is password protected.

Stage Three (Item Refinement and Test Assembly)

Focus group

A pool of test items was initially developed by the author. These items were presented to a group of six occupational therapists working in the field of education. A focus group was administered during which time feedback could be given regarding the item selection, font and paper used. Participants in this focus group were asked to complete a response opinion for each item indicating whether the item should remain, be revised or discarded from the test. For all the items of each of the eight tests developed, participants were asked three questions to clarify the appropriateness of each test and the items within each test. The questions focused on the participants' views of: (1) whether the section adequately sampled the content of commonly seen errors of this nature, (2) whether the section differentiated between younger children who would be more likely to reverse these letters or numbers and those who would not, and (3) whether the section provided information that would be useful in intervention of visual perceptual skills influencing letter and number directionality. Participants were also invited to make any additional comments and suggestions. Suggestions were considered and discussed prior to changes been made according to the consensus of the responses. Statistical analysis as well as clinical judgement was used to decide on the final item inclusions. This input was used to change the measure as described below.

All slants of letters and numbers were removed or minimised as the experience of the expert panel of reviewers suggested that students who tend to reverse letters and numbers do not slant their writing, and the print in books is also not slanted. Throughout the measure, the font size was increased to accommodate younger students who are accustomed to larger fonts. The individual letters and numbers were also spaced further apart so that students could easily mark the item they chose. There was general consensus that recognising reversed letters in words and reversed numbers in calculations was a good assessment of functional use of letters and numbers and therefore a good scale to maintain in the measure. The scales which targeted figure ground perception by confusing the words and numbers by adding additional lines were removed as the letters in words and numbers in calculations were considered sufficient assessment of figure ground perception. There was no consensus among the occupational therapists about the effectiveness of the reversed words in sentences as a definitive diagnostic tool and this section was thus removed. For the same reason, the section assessing visual closure of incomplete letters and numbers was removed. After these changes, there were eight scales left in the measure, incorporating visual discrimination (three scales), spatial orientation (one scale), sequencing (one scale), form constancy (one scale) and figure ground (two scales).

A prerequisite for items was that all reversed items (letters and numbers) had to reflect true orientation/reversal image. Words were chosen from the Dolch Basic Word List (English-Zone.com, 2009) for their familiarity and common exposure of these words to young students. It remained imperative however, that items remained representative of the constructs identified as important in visual perception. Clinical utility was considered in the ease of administration, cost and time effectiveness as well as discriminative power.

The Eight Tests

Eight tests were developed for the measure of letter and number reversal recognition. These tests included visual discrimination of upper and lower case letters as well as numbers, spatial orientation of letter and number pairs, form constancy of letters and numbers, letter and number sequencing and figure ground of letters in words and numbers in calculations.

In the Visual Discrimination of Upper Case Letters test, the student is presented with upper case letters in a random order where some letters are reversed and some letters are facing the right way. Each letter is spaced apart from the next, so that it is easier to isolate each letter. The student is required to indicate which of the upper case letters are reversed on the page. The examinee is given the following instructions: "This page has some letters written on it. Some of them are back to front or the wrong way around. Can you make a mark on (or show me) the ones that are facing the wrong way?" There are no practice items in this scale; however the letters in the first row may be used to explain the concept by demonstration to the very young student.

Visual Discrimination of Lower Case Letters consists of a similar random presentation of lower case letters where some are reversed and some are in the correct direction. The student is requested to indicate the reversed lower case letters. The examinee is given the following instructions: "This page has some small (lower case) letters on it. Some of them are back to front or the wrong way around. Can you make a mark (or show me) the ones that are facing the wrong way?" There are no practice items on this scale; however the first row of letters may be used as demonstration to explain the concept to the very young student.

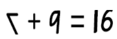
Visual Discrimination of Numbers has a random presentation of numbers in the reversed or correct orientation. The student is required to identify the reversed numbers on the page. The examinee is given the following instructions: "This page has some numbers written on it. Some of them are back to front or the wrong way around. Can you make a mark (or show me) on the ones that are facing the wrong way?" There are no practice items on this scale.

In the Spatial Orientation of letters and number pairs, a random selection of upper case, lower case letters and numbers are presented in pairs where each pair has one letter (or number) in the correct orientation and the same letter (or number) in the reversed orientation, as in Ƨ S. The student is required to identify the correctly oriented letter or number in each pair. The examinee is given the following instructions: "This page has some letters and numbers written in pairs. Look at each pair or group and decide which one is back to front or the wrong way around. Can you circle (or show me) the one that is facing the wrong way in each pair/group?" There are no practice items in this scale.

Letter and number sequencing consists of sequences of letters and numbers where the matching sequence has to be identified, for example 29 |Ƨ9 92 2P 29 Ƨ9, or where the student has to decide whether a set of sequences is the same or different (for example: saw/was; 213/213). When there are multiple choices from which the student can choose, the examinee is given the following instructions: "On this page there are some groups of letters and numbers. Look at each row of letters or numbers and find the one that is in the same order/sequence as the first one. Can you circle (or show me) the group that is in the same order/sequence, as the first group in each line?" The first item may be used for extensive explanation; however it is still included in the scoring. When there is a pair of sequences which the student must decide are the same or different, the following instruction is given: "This page has some letters and numbers written in pairs/groups. Look at each group and decide whether the group next to it is written in the same sequence/order. If the order/sequence is not the same, please cross it out (or point to it)." There are no practice items, but the first two items may be used for demonstration or additional explanation.

Form Constancy of Letters and Numbers requires the student to identify the reversed letter or number out of a selection of the same letter or number printed in a variety of fonts such as . The examinee is given the following instructions: "This page has letters and numbers written in a lot of different ways. Can you find the ones that are written back to front or the wrong way round and circle them / cross them out (or show them to me)?" The first item may be used for additional explanation, however the student's final response to this item is added to the score.

Figure Ground Letters in Words contains words selected from the 200 most commonly read words by young students, where some of the words contain a reversed letter as in . The student is required to identify these words. The examinee is given the following instructions: "This page has some words written on it. Some of the words have **one letter** that is written back to front or the wrong way around. Can you circle (or show me) the letters that are facing the wrong way in the words?" There are no practice items on this scale; however the first three words may be discussed in detail with the student if they find it difficult to grasp the instruction.

Figure Ground of Numbers in Calculations has calculations presented in a variety of layouts. The student is required to identify the reversed number within each calculation, for example, . The examinee is given the following instructions: "This page has some sums/calculations written on it. Some of the sums/calculations have **one number** that is written back to front or the wrong way around. Can you circle (or show me) the numbers that are facing the wrong way in the sums/calculations? Do not worry to work out the answers to the sums/calculations, as I have made sure all the answers are correct. We are only looking for the numbers that are the wrong way." There are no practice items on this scale; however the first calculation may be discussed in detail with the student if they find it difficult to grasp the instruction.

Pilot Study

A pilot study using the eight tests developed by this author was conducted on 20 students aged 5 to 10 years and was followed by an interview with each student. The eight tests were all completed during one single session. After the students had completed the eight tests, they were asked to provide verbal feedback on their subjective experience and opinion of the test by answering four questions: Would you mind telling me if you found the test interesting? What made it interesting/boring? What do you think should be done differently? How did doing the test make you feel? The child's responses were recorded by the examiner on an interview record sheet.

All the Pre-primary and Year One students reported that they found the eight tests too long and boring. They were unable to identify specifics of what made the tests boring except for the length. The Year Two and Year Three students had varying opinions about the length of the eight tests with some saying it was the right length and one saying it was too long. Comments received about what made the eight tests interesting were the novelty of the tests, the challenge to complete the tests without making any mistakes or not getting "caught by the tricks". The only comment about what could be done differently was that the tests should be shorter. Most students said they felt "OK" about doing the test. Some students said they did not like the test because it was difficult or they found the eight tests too lengthy, three of the students enjoyed completing the eight tests and requested to do it again. The sample size was too small and the spread between these students was too extensive to enable statistical analysis to be completed at this stage. The results of the eight tests completed by these 20 students were included in the statistical analysis after more data had been collected.

Stage Four: Data Collection and Data Entry

Seven primary schools in and around the Perth metropolitan area in Western Australia were used for the data collection. The data collection occurred over a three month period from October to December 2008. Students were included in the study if they were between the ages of five and ten years old. Each student who participated in the study required a completed parental consent form. Students were required to have a working knowledge of the English language to complete the assessment. Students with known developmental disorders, intellectual limitations, neurological impairments, learning difficulties, psychiatric disorder and/or visual difficulties, as identified on the parent report form, were not excluded from the participant group.

Sample for Rasch analysis

A convenience sample of 324 students was acquired. The inclusion of five public primary schools and two independent schools was ensured by subdividing the schools into categories prior to the selection process. These participants formed the sample for the main data collection. Every child from Pre-primary to Year Three in the participating schools was given an opportunity to participate in the study. The return rate of the parent consent forms was between 10% and 30% from the various schools. The sample included 177 girls and 146 boys. There were 45 Pre-primary students, 118 Year One students, 77 Year Two students and 83 Year Three students. Twenty-nine of the students were four or five years old, 71 were six years old, 92 were seven years old, 87 were eight years old, 39 were nine years old and six were ten years of age. Seventy-two students were reported by the parents as having had some form of intervention or diagnosis relating to learning difficulties, while 252 students had no record of previous or current interventions or learning difficulty. There were 68 students who attended private schools, while 256 students attended public schools.

Table 5.1:

Sample Characteristics n=324

Characteristic	Category	Sample Size
Gender	Boys	146
	Girls	177
Grade	Pre-primary	45
	Year 1	118
	Year 2	77
	Year 3	83
Age	4-5 years	29
	6 years	71
	7 years	92
	8 years	87
	9 years	39
	10 years	6
School Type	Public	256
	Private	68
Intervention	Yes	72
	No	252

Students were excluded if the parents did not complete the consent forms, or if the student chose not to participate in the study. Students with disabilities related to learning (intellectual impairment, diagnosed learning disability, neurological impairment, visual problem, or developmental delay) were not excluded from the study, as this data was used to establish the evidence of discriminatory sensitivity of the test.

Sample for focus groups

A convenience sample of 20 students was acquired for focus group discussions. Eleven of these students were interviewed as a pilot study, and nine students participated in the main interviews. Each of these students had previously participated in the completion of the scales. A second consent form was required for the interview portion of the study. This sample consisted of nine girls and eleven boys. Four of the students attended a private school. The eleven students in the pilot study were all in the Pre-primary year at school, while the nine students who participated in the main interviews were all in Year Two. Year Two students were chosen for the main focus groups in an attempt to access information from the younger students and also make the most of a higher level of meta-cognition.

Data Entry for the Rasch analysis

The data for each variable were entered into eight separate Excel files. A double-checking procedure was followed to ensure that the data were entered correctly. Any errors found were corrected. When it was determined that the data were entered correctly, the eight Excel files were converted to text files in word for subsequent analysis with the RUMM2020 computer program. The results of these analyses are reported in the Data Analysis Chapters following this chapter.

Data Entry for the focus groups

Data for the focus groups were recorded and transcribed. An audit trail were kept for the transcribed material. All identifying data was removed from the transcribed files to maintain anonymity. The transcribed data were analysed for common themes which are reported in Chapter ten.

Stage Five: (Data Analysis)

Statistical analysis for questionnaire data

The data were analysed using the Rasch Uni-dimensional Measurement Model computer software (Andrich et al., 2005). Data analysis output was generated to meet the requirements for contributing to the fit to a Rasch measurement model and to the evidence categories for construct validity according to the Standards for Educational and Psychological Testing (American Educational Research Association et al., 1999). The RUMM computer program provides statistics in relation to conformity with the Rasch Measurement Model (fit to the model), item difficulty and student measures on the same linear scale, consistency of test scoring, item dissemination and targeting. These are now briefly outlined in the next section and they are reported in more detail in the data analysis chapters.

Analysis of focus group data

The focus group data were analysed using the Miles and Huberman (1994) approach. The responses given by the students were considered and coded according to the indicators and concepts implicated by the students comments (Punch, 2005). Meaning was abstracted from their descriptions and comments according to the indicators that were identified. Similar concepts were clustered together with reference to the context in which they were given. Attention was given to any change of opinion from the students participating in the study. Attention was focused on comments when students related their comments to their own experience. Themes were sought to reveal the general impression of the students with regards to the eight scales.

Stage Six: Reporting Results

Rasch analysis results

In stage six, conformity to the Rasch Measurement Model was established for each of the eight tests. This meant that there were eight reliable scales from which valid inferences could be drawn. This is in line with international measurement standards reported by the American Educational Research Association (1999) and the Journal of Applied Measurement (2008) website.

Evidence based on test content

The item content for each of the eight tests was considered by a group of occupational therapy experts through written comments and oral comments in a focus group, to be valid. The items for the eight tests were sourced from reviewing the available literature and enlisting clinicians and experts in the field to review the items. Test items were required to meet the following criteria: (1) no ambiguity in the test items or the instructions; (2) letters had to relate to the script that students were taught in class; (3) only letters that represented a clear mirror image, or inverted mirror image, were used in identifying reversal tendencies; (4) words used in the tests had to relate to words primary school children are commonly exposed to, therefore the 200 most commonly used words (Ramsay, 2007) took preference in the item selection; and (5) items were linked to at least one of the visual perceptual constructs (visual discrimination, visual form constancy, visual figure ground, visual spatial orientation and visual sequencing) chosen for testing.

Evidence for logical consistent response scoring

Logical and consistent item scoring (zero for incorrect and one for correct) was checked through Scoring Category Curves. The Scoring Category Curves showed appropriate links between different measures on the linear scale and the probability of scoring zero or one for each item in each of the eight scales.

Evidence based on internal structure

Evidence based on the internal structure (that is, the reliability) of the eight tests was gathered by checking the item fit and student fit to the measurement model, and overall fit to the measurement model. Item Characteristic Curves were created to show good dissemination and a Student Separation Index that shows measures are well separated in comparison to errors.

Focus Group Results

Reporting of the focus group data was descriptive and presents the implications of the data related to future improvement of the scales (Punch, 2005). Some statements made by the students are presented according to the identified themes and an interpretation of these comments was made. The results are presented according to comments relating to each scale as well as comments on how to overcome confusion. Inferences are drawn about the meaning of statements made by the students.

The next chapter, Chapter Six, is the first of the data analysis chapters where the RUMM output is explained and interpreted for Visual Discrimination of Upper Case Letters, Visual Discrimination of Lower Case Letters and Visual Discrimination of Numbers.

CHAPTER SIX

DATA ANALYSIS (PART ONE)

RASCH MEASUREMENT OF VISUAL DISCRIMINATION OF UPPER CASE LETTERS, LOWER CASE LETTERS AND NUMBERS

Eight uni-dimensional, linear scales were created with the Rasch Uni-dimensional Measurement Models (RUMM2020) computer program (Andrich et al., 2005). These linear scales measured: (1) Visual Discrimination of Upper Case Letters; (2) Visual Discrimination of Lower Case Letters; (3) Visual Discrimination of Numbers; (4) Spatial Orientation of Upper Case Letter, Lower Case Letter and Number Pairs; (5) Sequencing of Letters and Numbers; (6) Form Constancy of Letters and Numbers; and (7) Letters in Words and (8) Numbers in Calculations. The RUMM analyses to create these linear scales are presented in the following data analysis chapters, the first of which is the present chapter, Chapter Six.

Chapter Six Data Analysis (Part One) presents an in-depth Rasch analysis of Visual Discrimination of Upper Case Letters; Visual Discrimination of Lower Case Letters and Visual Discrimination of Numbers, as these scales relate to visual discrimination, whereas the other scales relate to other visual perceptual concepts and will thus be discussed separately. This chapter describes the measurement results in terms of Rasch measurement fit statistics including global item and person fit to the measurement model, dimensionality, person separation indices, distribution of item-person interactions, and discrimination. There is some discussion about the non-fitting items in addition to good fitting items and the person-item threshold distribution (targeting). This is followed by mean Rasch measures by group and final items for the Visual Discrimination Scales discussion. Finally, inferences drawn from the linear Rasch measurement data analysis and the summary of the results are presented.

Initial Rasch Analysis

(Analysis for Visual Discrimination of Letters and Numbers)

An initial Rasch analysis was performed on the original items for Visual Discrimination of Upper Case Letters (30 items), Visual Discrimination of Lower Case Letters (36 items) and Visual Discrimination of Numbers (20 items) where each item was scored in one of two categories (incorrect answer scored zero and correct answer scored one). Twelve of the initial 30 items of Visual Discrimination of Upper Case Letters were deleted due to item misfit statistics. The remaining 18 items were found to have a reasonable fit to the measurement model for the 324 persons included in this study. For Visual Discrimination of Lower Case Letters, five of the initial 36 items were deleted due to item misfit statistics. The remaining 31 items displayed a good fit to the measurement model. In the Visual Discrimination of Numbers section, six of the initial 20 items were removed because of item misfit statistics with the remaining 14 items found to have a good fit to the measurement model.

The Rasch analysis with the RUMM program does not indicate how to alter an item in order to make it fit the measurement model. In order to include, in a future measure, the deleted items which were initially considered conceptually valid, these would need to be changed and re-tested. One suggestion, from anecdotal evidence, is to change the font used in the scale to something with which the students might be more familiar in printed context. This will be discussed further in a later chapter.

Final Rasch Analysis Results

The following material shows the results for the final Rasch analysis for Visual Discrimination of Upper Case Letters (18 items), Visual Discrimination of Lower Case Letters (31 items) and Visual Discrimination of Numbers 14 items).

Summary of Fit Statistics

The RUMM2020 program estimates an item-person interaction which establishes the overall fit statistics that determine whether the item estimations contribute meaningfully to the measurement of one construct. This calculation thus examines the consistency with which students responses agree with the calculated difficulty of each item on the scale. The standardised fit residual statistics (see Table

6.1) have a distribution with a mean near zero and a standard deviation near one when the data fit the measurement model (Andrich, 1985), as is the case with these three measures. This means too that there is a good pattern of person and item responses consistent with a Rasch measurement model.

Dimensionality

For Visual Discrimination of Upper Case Letters, there was an item-trait interaction chi-square of 42.07 with df = 0.94 and a probability of 0.23. This means that the scale is constructed with reasonable agreement amongst the students about the linear progressive difficulty of the items. The item-trait interaction chi-square for Visual Discrimination of Lower Case Letters was 136.85 with df = 0.96 and a probability of 0.20, showing a similar reasonable agreement amongst the students about the linear progressive difficulty of the items along the scale. For Visual Discrimination of Numbers, the item-trait interaction chi-square was 68.34 with df = 0.92 and a probability of 0.12 respectively, again showing reasonable agreement about the item difficulties along the scale.

Table 6.1:

Global Item and Student Fit Residual Statistics (N=324) for Visual Discrimination of Upper Case Letters (I=18, Visual Discrimination of Lower Case Letters (I=31) and Visual Discrimination of Numbers (I=14))

	ITEMS		PERSONS	
	Location	Fit Residual	Location	Fit Residual
Visual Discrimination of Upper Case Letters (I=18)				
Mean	0.00	-0.70	2.99	-0.44
Standard Dev.	0.77	1.36	0.81	0.79
Visual Discrimination of Lower Case Letters (I=31)				
Mean	0.00	-0.50	2.68	-0.56
Standard Dev.	1.21	1.55	1.31	1.02
Visual Discrimination of Numbers (I=14)				
Mean	0.00	-0.47	2.33	-0.42
Standard Dev.	1.18	0.94	1.24	0.92

Comment on Table 6.1:
Fit residuals have a mean near zero and a standard deviation near one when the data fit the measurement model (as is the case here). This reflects good consistency of item and student scoring patterns.
'I' stands for item

Person Separation Index

The Person Separation Index is an estimate of the true score variance among the students and the estimated observed score variance using the estimates of their ability measures and the standard error of these measures (Andrich & van Schoubroeck, 1989). For Visual Discrimination of Upper Case Letters, Lower Case Letters and Numbers, the Person Separation Indices are 0.55, 0.81 and 0.75 respectfully. For a good measure, it is desirable that this index should be 0.9 or greater, as it is an indicator that the student measures are separated by more than their standard errors (Andrich & van Schoubroeck, 1989). Based on this index, the Visual Discrimination Lower Case Letters and Visual Discrimination Numbers scales demonstrate acceptable separation, but Visual Discrimination Upper Case Letters requires improvements to the measure in any future use.

Individual Item Fit

Items are ordered by calibrated values to evaluate their fit to the measurement model. The location of each item on the scale is the item difficulty in standard units, called logits (log odds of answering successfully). All the items fit the measurement model with probabilities greater than p=0.10 (see Table 6.2). The residuals shown in Table 6.2 represent the difference between the observed responses and the expected responses calculated from the Rasch measurement parameters. Standardised residuals should fall within the range of -2 and +2. Table 6.2 shows that all items for Visual Discrimination Upper Case Letters have acceptable residuals except for item 30.

For Visual Discrimination of Lower Case Letters, all the items fit the measurement model with probabilities greater than p=0.08 (see Table 6.3), but a few of the residuals are a little outside what might be considered good limits.

For Visual Discrimination of Numbers, all the items fit the measurement model with probabilities greater than p=0.05 (see Table 6.4) and residuals are very satisfactory.

Table 6.2:

Individual Item Fit Statistics for Visual Discrimination Upper Case Letters

Item	Location	SE	Residual	DegFree	ChiSq	DegFree	Prob
2	-1.58	0.51	-1.99	136.94	3.35	2	0.19
24	-0.92	0.39	-1.40	136.94	2.12	2	0.35
27	-0.57	0.34	-0.86	136.94	1.81	2	0.40
18	-0.56	0.34	-1.04	136.94	1.26	2	0.53
25	-0.43	0.32	-1.48	136.94	1.69	2	0.43
5	-0.35	0.31	-1.17	136.94	2.21	2	0.33
1	-0.32	0.31	-1.42	136.94	4.45	2	0.11
22	-0.18	0.29	-0.31	136.94	2.69	2	0.26
28	-0.18	0.29	-0.99	136.94	0.97	2	0.62
17	0.02	0.27	-1.14	136.94	2.89	2	0.24
11	0.11	0.27	-0.52	136.94	1.36	2	0.51
15	0.17	0.26	-1.71	136.94	3.27	2	0.19
23	0.31	0.25	-0.88	136.94	1.62	2	0.44
4	0.32	0.25	-1.74	136.94	3.33	2	0.19
3	0.39	0.24	-0.50	136.94	4.53	2	0.10
9	0.66	0.22	-0.67	136.94	1.37	2	0.50
8	1.29	0.19	1.44	136.94	1.15	2	0.56
30	1.79	0.18	3.84	136.94	1.99	2	0.37

Notes on Table 6.2, 6.3 and 6.4:

1. Location refers to the difficulty of the item on the linear scale.
2. SE means Standard Error, and refers to the degree of uncertainty in a value.
3. Residual represents the difference between the expected value of an item, calculated according to the Rash measurement model and the actual value.
4. DegFree stands for degrees of freedom, and refers to the number of scores in a distribution that are free to change without changing the mean distribution.
5. ChSq stands for Chi-square
6. Prob relates to the probability based on the Chi-square and refers to the levels of certainty to which an item fits the measurement model.

Table 6.3:

Individual Item Fit Statistics for Visual Discrimination Lower Case Letters

Item	Location	SE	Residual	DegFree	ChiSq	DegFree	Prob
9	-2.06	0.42	-2.47	248.71	4.81	4	0.31
8	-1.83	0.38	-0.61	248.71	4.05	4	0.40
6	-1.51	0.33	-1.97	248.71	4.69	4	0.32
10	-1.30	0.31	-0.22	248.71	4.16	4	0.39
29	-1.19	0.29	-2.46	248.71	3.49	4	0.48
1	-1.15	0.29	-1.72	248.71	2.39	4	0.66
13	-1.10	0.28	-2.05	248.71	2.14	4	0.71
16	-1.08	0.28	-2.74	248.71	5.91	4	0.21
19	-1.06	0.28	-0.98	248.71	2.17	4	0.71
34	-0.90	0.26	-1.09	248.71	1.50	4	0.83
31	-0.70	0.25	-0.21	248.71	3.04	4	0.55
28	-0.54	0.23	-0.90	248.71	6.39	4	0.17
17	-0.49	0.23	-0.85	248.71	3.32	4	0.51
21	-0.35	0.22	-0.82	248.71	4.98	4	0.29
35	-0.21	0.21	0.16	248.71	6.37	4	0.17
25	-0.11	0.20	-2.23	248.71	5.46	4	0.24
23	-0.11	0.20	-2.82	248.71	7.06	4	0.13
30	0.11	0.19	-0.52	248.71	3.41	4	0.49
3	0.12	0.19	-0.76	248.71	2.34	4	0.67
2	0.26	0.18	-0.91	248.71	6.30	4	0.18
26	0.34	0.18	-1.71	248.71	2.14	4	0.58
7	0.81	0.16	-0.81	248.71	7.80	4	0.10
14	0.99	0.16	0.21	248.71	6.76	4	0.15
15	1.12	0.15	0.79	248.71	5.81	4	0.21
33	1.28	0.15	2.03	248.71	4.18	4	0.38
12	1.46	0.15	1.27	248.71	2.48	4	0.65
24	1.59	0.14	1.08	248.71	3.94	4	0.41
31	1.62	0.14	1.27	248.71	3.56	4	0.47
36	1.78	0.14	1.61	248.71	2.24	4	0.69
11	1.93	0.14	1.41	248.71	5.02	4	0.29
4	2.26	0.14	3.47	248.71	8.25	4	0.08

Table 6.4:

Individual Item Fit Statistics for Visual Discrimination Numbers

Item	Location	SE	Residual	DegFree	ChiSq	DegFree	Prob
6	-1.79	0.33	-0.98	191.29	1.92	4	0.75
17	-1.34	0.28	-0.43	191.29	3.26	4	0.52
2	-1.08	0.25	0.68	191.29	8.63	4	0.07
4	-0.81	0.23	-1.65	191.29	3.98	4	0.41
7	-0.79	0.23	-1.46	191.29	6.20	4	0.18
3	-0.78	0.23	-1.25	191.29	5.83	4	0.21
19	-0.38	0.21	-0.19	191.29	5.60	4	0.23
10	-0.33	0.20	-0.89	191.29	2.89	4	0.58
9	0.69	0.16	-0.07	191.29	1.98	4	0.74
18	0.93	0.16	0.33	191.29	1.22	4	0.87
5	0.96	0.16	-0.75	191.29	6.18	4	0.19
13	1.43	0.15	-0.38	191.29	2.75	4	0.60
11	1.53	0.15	-1.30	191.29	9.58	4	0.05
20	1.78	0.15	1.80	191.29	8.32	4	0.08

Notes on Table 6.4:

1. Location refers to the difficulty of the item on the linear scale.
2. SE means Standard Error, and refers to the degree of uncertainty in a value.
3. Residual represents the difference between the expected value of an item, calculated according to the Rash measurement model and the actual value.
4. DegFree stands for degrees of freedom, and refers to the number of scores in a distribution that are free to change without changing the mean distribution.
5. ChSq stands for Chi-square
6. Prob relates to the probability based on the Chi-square and refers to the levels of certainty to which an item fits the measurement model.

Targeting

The RUMM2020 program produces a student-measure item-difficulty or targeting graph on which the student measures are placed on the same scale as the item difficulties in standard units called logits. For Visual Discrimination of Upper Case Letters (see Figure 6.1), this targeting graph shows that the student measures cover a range of about -0.8 to +3.5 logits and the item difficulties cover a range of about -1.5 to +1.8 logits. From the graph it can be seen that many students (about 290) were able to answer the items correctly and the targeting of the items needs to be improved in any future use of the scale by adding in some harder items to 'cover' the students with the higher measures.

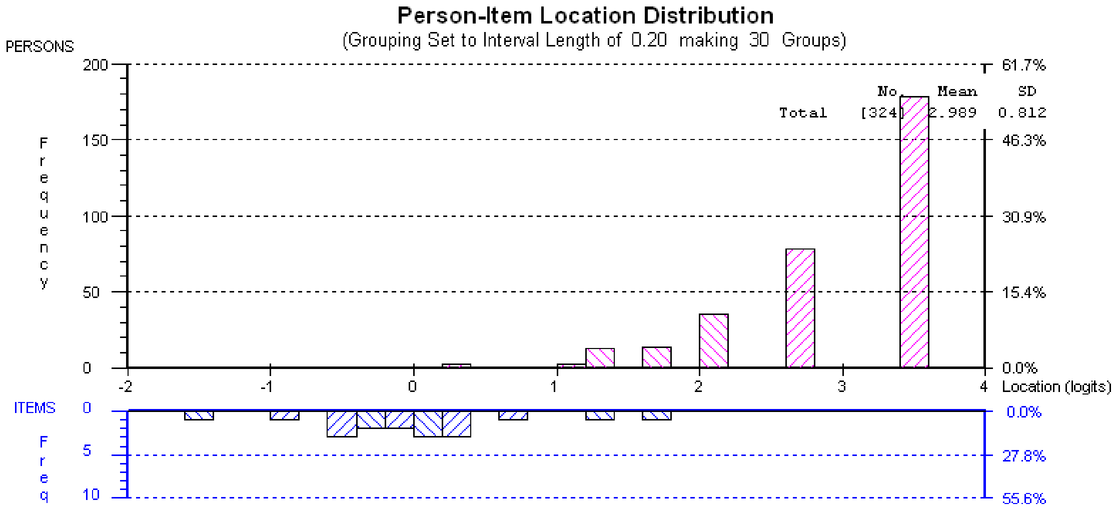


Figure 6.1 Targeting Graph for Visual Discrimination Upper Case Letters
Note: Student measures are on the upper side in logits. Item difficulties are on the lower side of the same scale in logits. Many students (about 290) answered the items correctly.

For Visual Discrimination of Lower Case Letters (see Figure 6.2), the targeting graph shows that the student measures cover a range of about -1.0 to +4.5 logits and the item difficulties cover a range of about -2.2 to +2.3 logits. From the graph it can be seen that many students (about 175) were able to answer the items correctly and the targeting of the items needs to be improved in any future use of the scale by adding in some harder items to 'cover' the students with the higher measures.

For Visual Discrimination of Numbers (see Figure 6.3), the targeting graph shows that the student measures cover a range of about -1.2 to +3.8 logits and the item difficulties cover a range of about -1.8 to +1.8 logits. From the graph it can be seen that many students (about 215) were able to answer the items correctly and the targeting of the items needs to be improved in any future use of the scale by adding in some harder items to 'cover' the students with the higher measures.

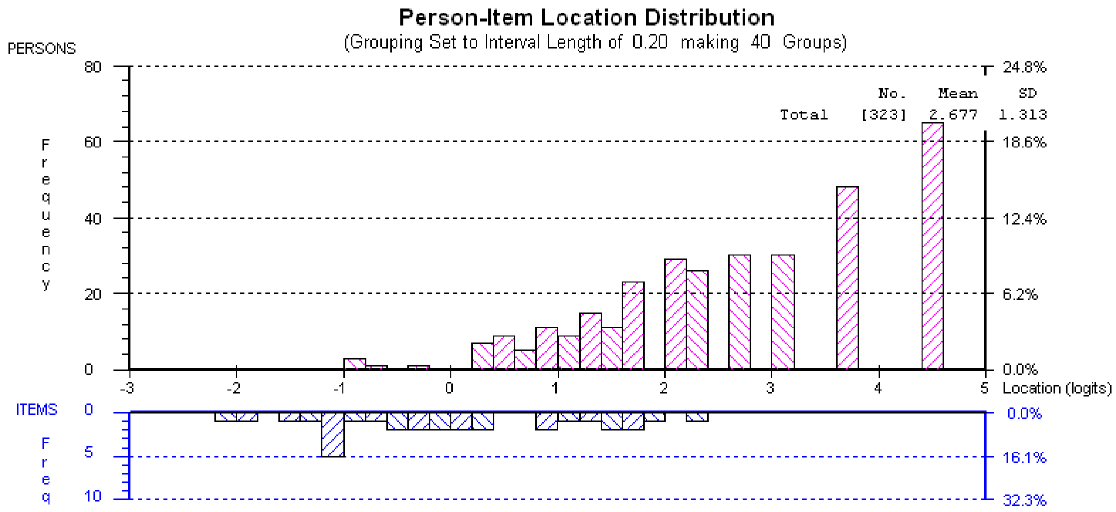


Figure 6.2: Targeting Graph for Visual Discrimination Lower Case Letters
Note: Student measures are on the upper side in logits. Item difficulties are on the lower side of the same scale in logits. Many students (about 175) answered the items correctly.

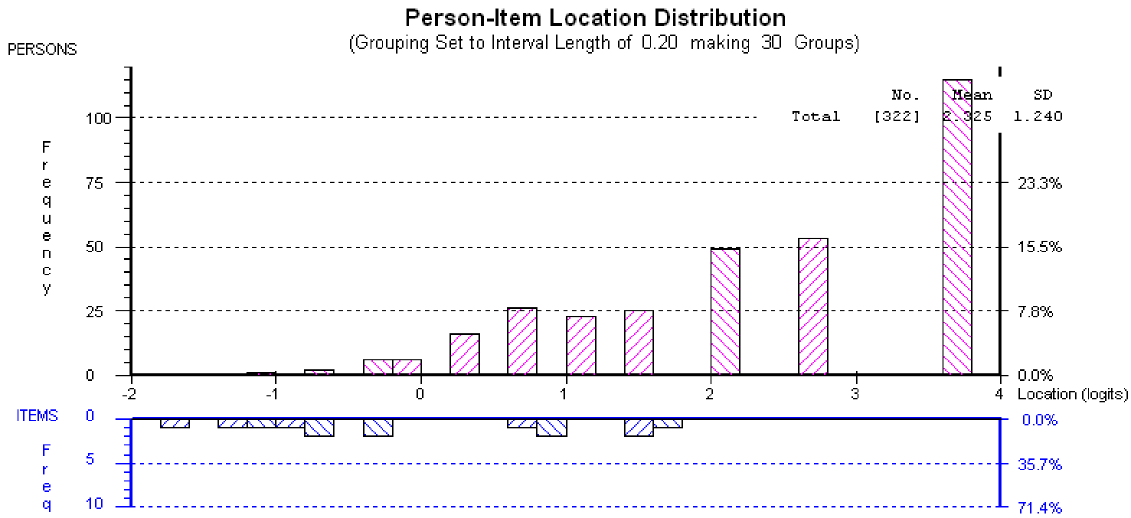


Figure 6.3: Targeting for Visual Discrimination Numbers
Note: Student measures are on the upper side in logits. Item difficulties are on the lower side of the same scale in logits. Many students (about 215) answered the items correctly.

Discrimination

Item Characteristic Curves examine the relationship between the expected response and the mean group student measures. These curves display how well the item discriminates between groups of persons. An example of one item characteristic curve for each construct will be presented. Figure 6.4 shows the Item Characteristic Curve for Item 1 Visual Discrimination of Upper Case Letters. This curve shows that the item discriminates well for students with different measures. The Item Characteristic Curves for all the other items were checked and found to be satisfactory (but are not reported here to avoid unnecessary repetition).

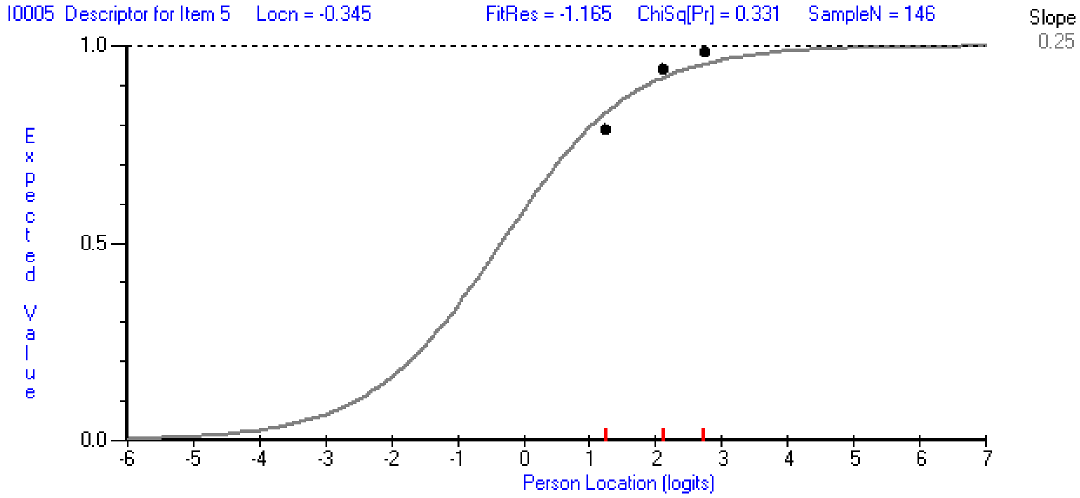


Figure 6.4: Item Characteristic Curve: Item 1 - Visual Discrimination Upper Case Letters

Figures 6.5 and 6.6 respectively show the Item Characteristic Curves for Item 28 of Visual Discrimination Lower for Case Letters and Item 13 of Visual Discrimination of Numbers. Both these items discriminate well for students with different measures. The Item Characteristic Curves for all the other items in both measures were checked and found to be satisfactory (but are not reported here to avoid unnecessary repetition).

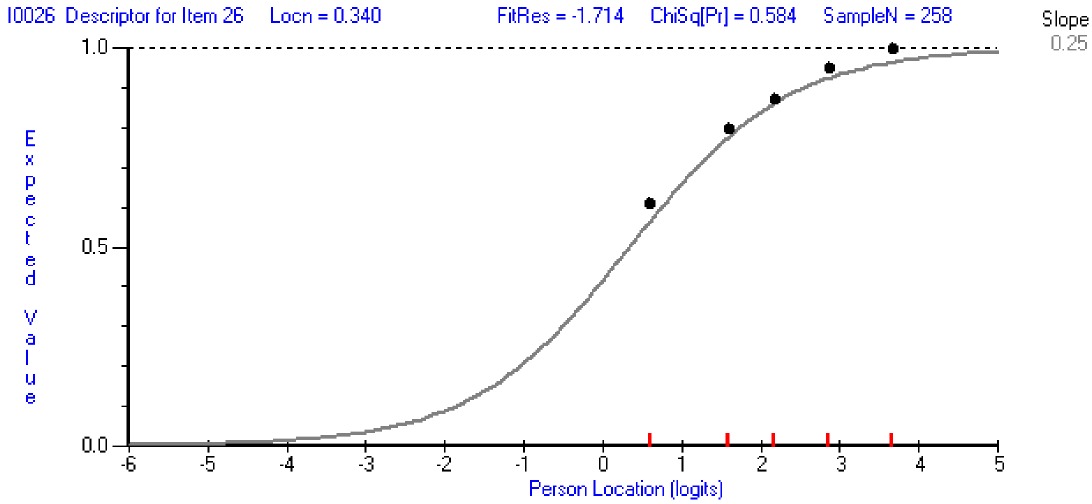


Figure 6.5: Item Characteristic Curve: Item 28-Visual Discrimination Lower Case Letters

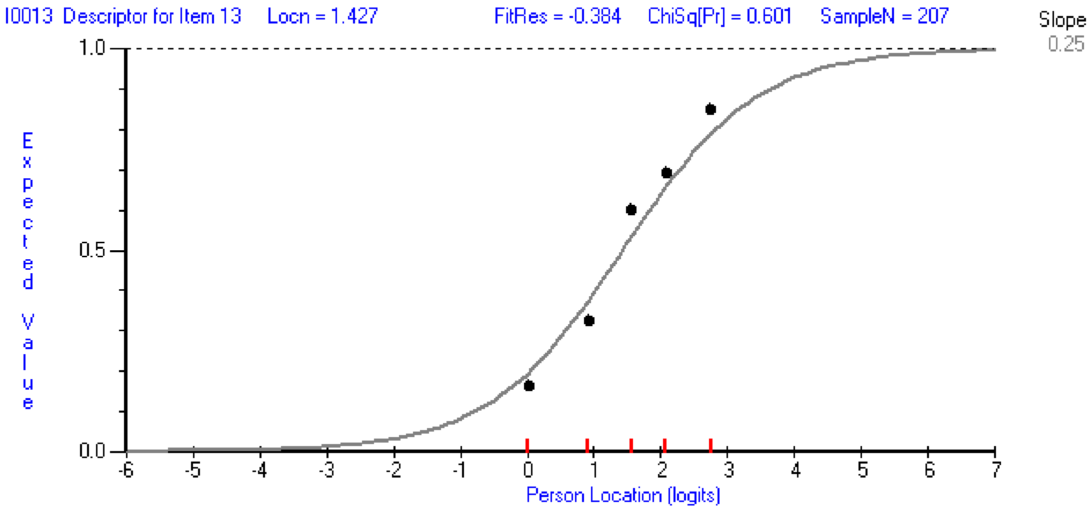


Figure 6.6: Item Characteristic Curve: Item 13 – Visual Discrimination Numbers

Consistency of Use of Scoring Categories

The RUMM2020 program produces graphs of the scoring categories for each item. The Scoring Category Curves show the relationship between the probability of scoring in each category (zero for wrong and one for right) on each item. Figure 6.7 is the Scoring Category Curve for item 1 of Visual Discrimination Upper Case Letters. This figure shows that the scoring was done logically and consistently. When students have low measures on item 1, then they have a high probability of obtaining a zero score (answer wrong) and, when they have a high measure, they have a high probability of scoring 1 (answer correct). The Scoring Category Curves for all the other items were checked and they were satisfactory too. The Scoring Category Curves for all the items of the other two variables, Visual Discrimination Lower Case Letters and Visual Discrimination Numbers, were checked and they were also found to be satisfactory, but they are not presented here to avoid too much repetition.

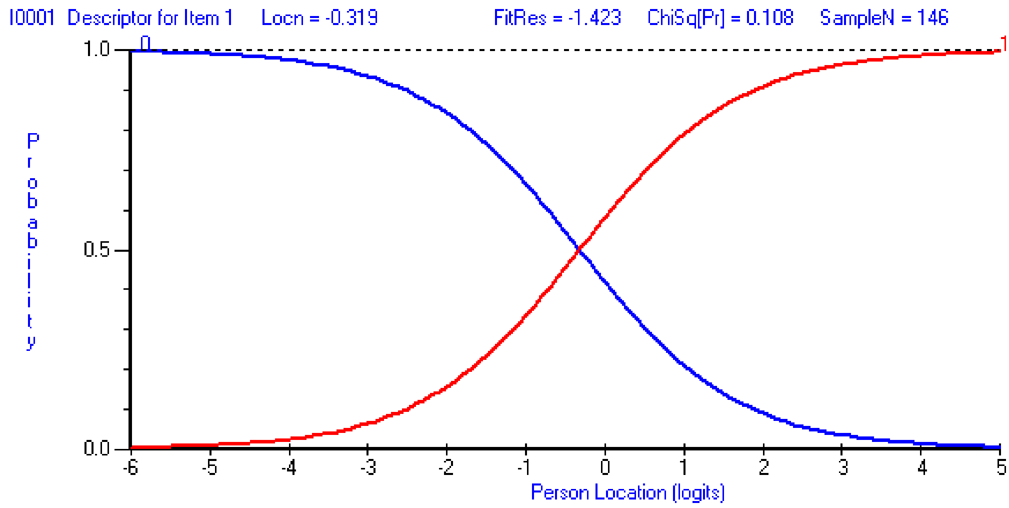


Figure 6.7: Scoring Category Curve: Item1 – Visual Discrimination Upper Case Letters

Characteristics of the Sample (VDUCL)

The measures for Visual Discrimination of Upper Case Letters were displayed in a graphical format separated by gender (Figure 6.8), type of school (Figure 6.9), age (Figure 6.10), grade (Figure 6.11) and whether intervention had been received (Figure 6.12). The mean differences were then tested for statistical significance using t-tests. Females have a higher mean measure than males for Visual Discrimination of Upper Case Letters but this is not statistically, significantly different (t=1.05, df=321, p=0.15). Public school students have a higher mean measure than private school students for Visual Discrimination of Upper Case Letters and this is statistically, significantly different (t=2.63, df=322, p=0.005). As would be expected, the mean measures generally increased by age from Four years of age (lowest) to nine years of age (highest) and this was statistically, significantly different (t=5.07, df=66, p<0.000). Again, as expected, the mean measures generally increased by grade from Pre-primary (lowest) to Year 3 (highest) and this was statistically, significantly different (t=8.27, df=127, p<0.000). While the mean measures for no intervention were higher than for intervention, this was not statistically, significantly different (t=1.44, df=322, p=0.07).

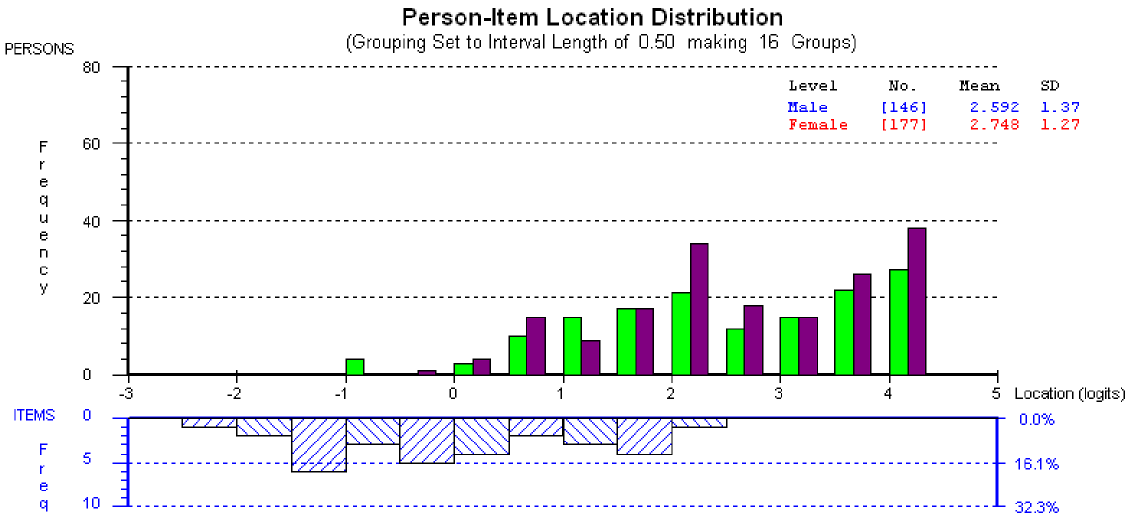


Figure 6.8: Target Graph by Gender for Visual Discrimination for Upper Case Letters

Note: There is a colour error in the RUMM program. Purple represents the females (not red) and green represents the males (not blue).

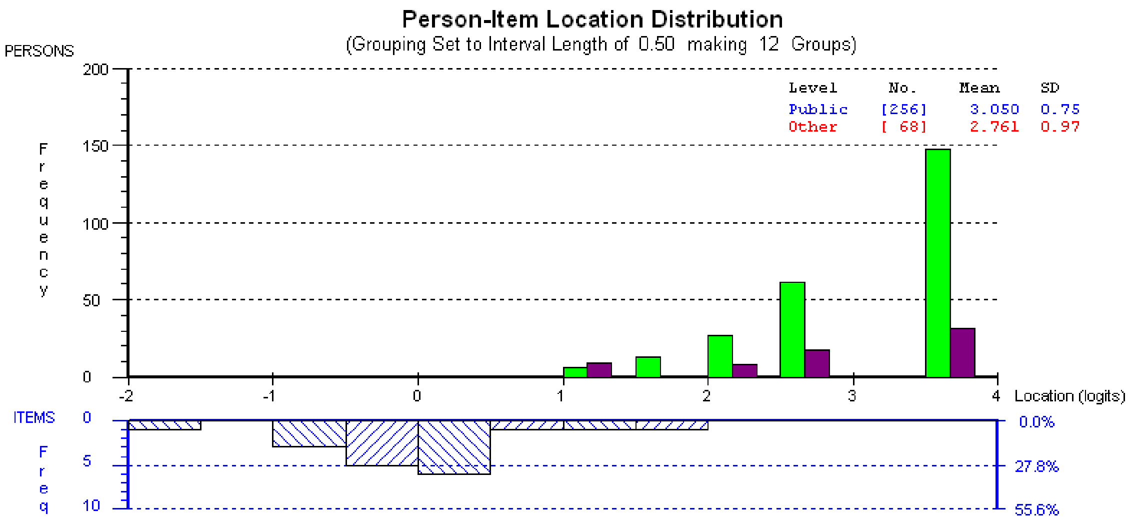


Figure 6.9: Target Graph by Type of School for Visual Discrimination for Upper Case Letters

Note: There is a colour error in the RUMM program. Purple represents other schools (not red) and green represents the public schools (not blue).

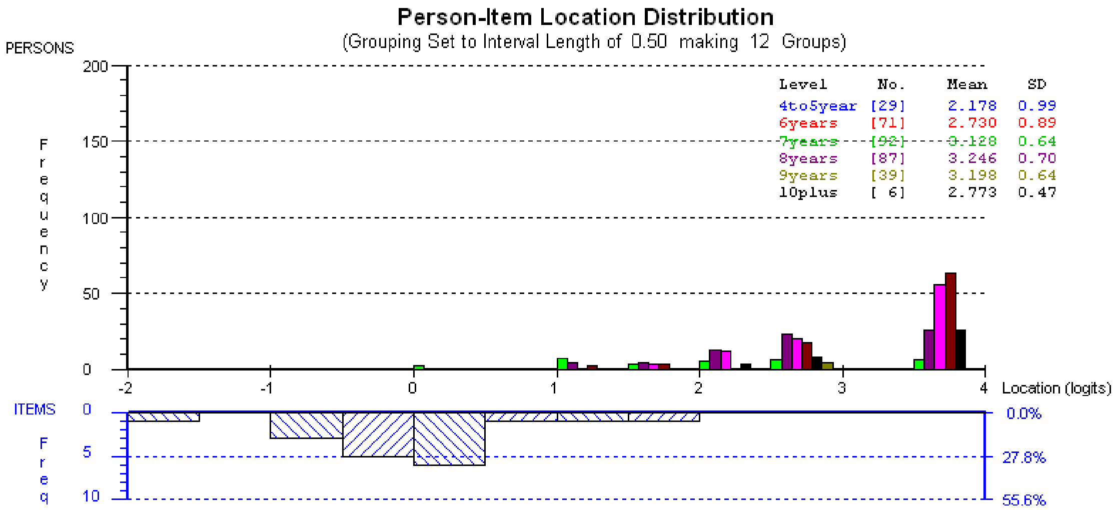


Figure 6.10 Target Graph by Age for Visual Discrimination for Upper Case Letters

Note: There is a colour error in the RUMM program. Four and five year olds are represented by green (not blue), six year olds are represented by Purple (not red), seven year olds are represented by pink (not green), eight year olds are represented by maroon (not purple), nine year olds are represented by black (not brown-green) and ten years and above are represented by brown-green (not black).

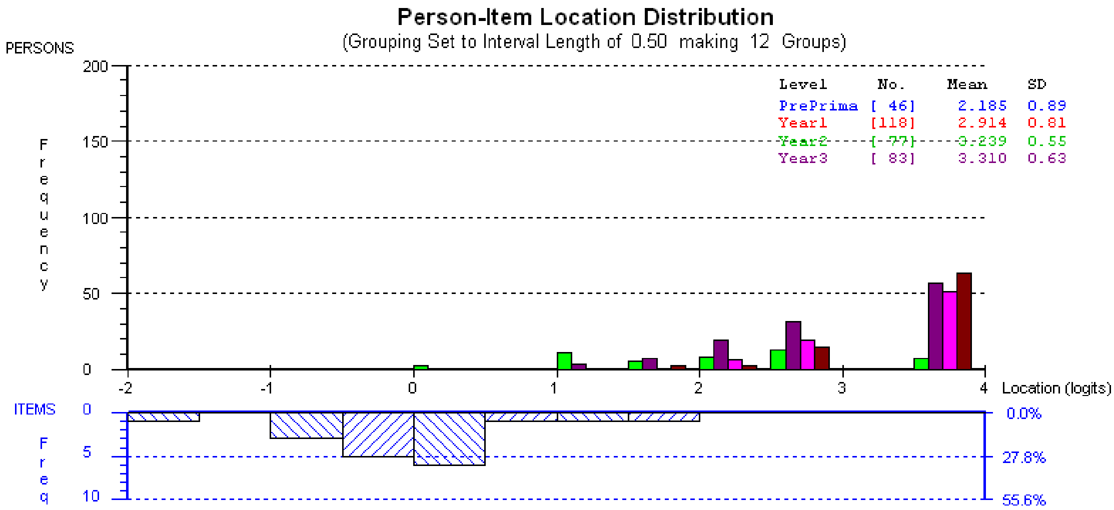


Figure 6.11: Target Graph by School Year for Visual Discrimination for Upper Case Letters

Note: There is a colour error in the RUMM program. Pre-primary is represented by green (not blue), Year 1 is represented by purple (not red), Year 2 is represented by pink (not green), and Year 3 is represented by maroon (not purple).

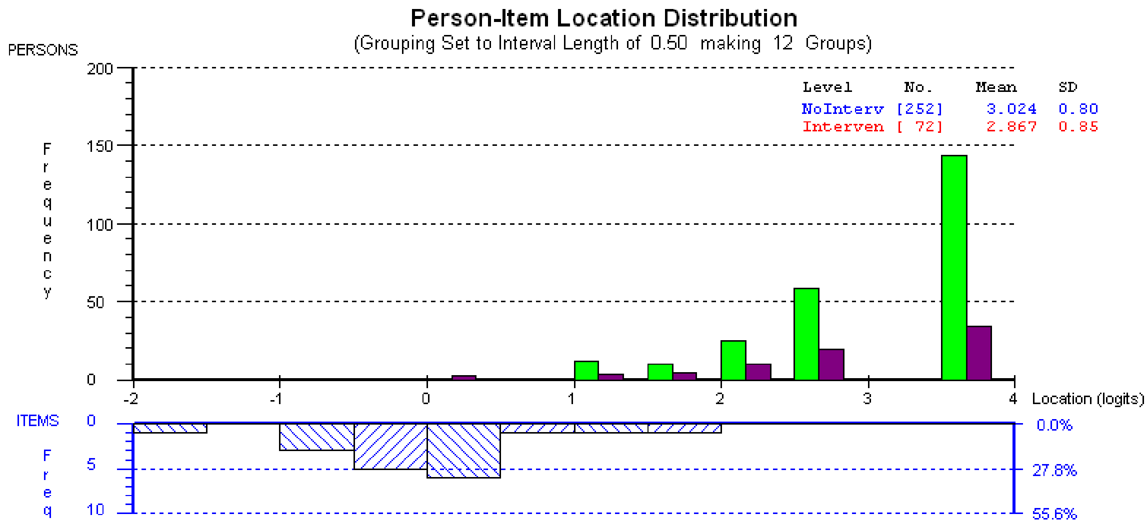


Figure 6.12: Target Graph by Intervention for Visual Discrimination for Upper Case Letters
Note: There is a colour error in the RUMM program. Green represents no intervention and purple intervention.

The graphical data for Visual Discrimination of Lower Case Letters was checked in the RUMM computer program but is not produced here to avoid too much repetition but the graphs are similar to those produced for Visual Discrimination of Upper Case Letters. Females have a higher mean measure than males for Visual Discrimination of Lower Case Letters but this is not statistically, significantly different (t=1.06, df=321, p=0.15). Public school students have a higher mean measure than private school students for Visual Discrimination of Lower Case Letters and this is not statistically, significantly different (t=0.90, df=321, p=0.19). As would be expected, the mean measures generally increased by age from four years old (lowest) to ten year old or older (highest) and this was statistically, significantly different (t=10.01, df=66, p<0.000). Again, as expected, the mean measures generally increased by grade from Pre-primary (lowest) to Year 3 (highest) and this was statistically, significantly different (t=15.98, df=127, p<0.000). While the mean measure for no intervention was higher than for intervention, this was not statistically significantly different (t=1.24, df=321, p=0.10).

The graphical data for Visual Discrimination of Numbers was also checked in the RUMM computer program but is not produced here to avoid too much repetition; however the graphs are similar to those produced for Visual Discrimination of Upper Case Letters. Females have a higher mean measure than males for Visual Discrimination of Lower Case Letters but this is not statistically, significantly different (t=1.78, df=320, p=0.04). Public school students have a higher mean measure than private school students for Visual Discrimination of Lower Case Letters and this is not statistically, significantly different (t=1.39, df=320, p=0.03). As would be expected, the mean measures generally increased by age from four years old (lowest) to ten years old or older (highest) and this was statistically, significantly different (t=8.79, df=65, p<0.000). Again, as expected, the mean measures generally increased by grade from Pre-primary (lowest) to Year 3 (highest) and this was statistically, significantly different (t=13.01, df=125, p<0.000). While the mean measure for no intervention was higher than for intervention, this was not statistically significantly different (t=1.21, df=320, p=0.10).

Final Items for the Three Visual Discrimination Scales

The final 18 items and their difficulties are presented, in order from easiest to hardest, in Table 6.5 for Visual Discrimination of Upper Case Letters. The students found it easy to discriminate whether the letter was revered or not for upper case letters that were symmetrical around the midline, for example the T, X, Y. They found it moderately easy to discriminate upper case letters that had an upright line on the left of the letter (e.g. E, R, B), moderately difficult to discriminate upper case letters that were rounded (e.g. S, G, U) and most difficult to discriminate upper case letters that were in a reversed orientation (e.g. ꟼ, ꓘ, Ǝ).

In the Visual Discrimination of Lower Case Letters (see Table 6.6 for the 31 item difficulties ordered from easy to hard), students found it easy to discriminate reversed and non-reversed letters that began with a long downward stroke on the left, such as the k, h, b, and moderately easy to discriminate lower case letters that only consisted of a body, for example o, r, u, c. Lower case letters that consisted of only a body and were also reversed were moderately difficult to discriminate, for example ɘ, ɔ, ƨ; while lower case letters with a body as well as a tail and in the reversed orientation (e.g. ϱ, ʃ, ƹ) were the most difficult to discriminate.

In the Visual Discrimination of Numbers (see Table 6.7 for the 14 item difficulties ordered from easy to hard), the students found it very easy to discriminate reversed and non-reversed numbers when the number could not be reversed such as the 1 and 8, and found it moderately easy to discriminate numbers that could be reversed but were presented in the correct orientation such as 2, 4, and 5. Moderate difficulty was experienced in discriminating reversed numbers for example ∂,+,ᐸ with the reversed 3 (Ɛ) being the most difficult number for students to discriminate.

Table 6.5

Difficulties for 18 Final Items in Visual Discrimination for Upper Case Letters Scale

Item No	Item Letter	Difficulty	SE	Item No	Item Letter	Difficulty	SE
2 (easiest)	T	-1.58	0.51	17	S	+0.02	0.27
24	X	-0.92	0.39	11	P	+0.11	0.27
27	Y	-0.57	0.34	15	G	+0.17	0.26
18	M	-0.56	0.34	23	U	+0.31	0.25
25	Q	-0.43	0.32	4	L	+0.32	0.25
5	A	-0.35	0.31	3	ꟼ	+0.39	0.24
1	E	-0.32	0.31	9	D	+0.66	0.22
22	R	-0.18	0.29	8	ꓘ	+1.29	0.19
28	B	-0.18	0.29	30	Ǝ (hardest)	+1.79	0.18

Note: Items are ordered from easiest (item 2, -1.58 logits) to hardest (item 30, +1.79 logits)

Table 6.6:

Difficulties for 31 Final Items in Visual Discrimination for Lower Case Letters Scale

Item No	Item Letter	Difficulty	SE	Item No	Item Letter	Difficulty	SE
9 (easiest)	k	-2.06	0.42	23	a	-0.11	0.20
8	h	-1.83	0.38	30	q	+0.11	0.19
6	b	-1.51	0.33	3	s	+0.12	0.19
10	n	-1.30	0.31	2	ɥ	+0.26	0.18
29	ɼ	-1.20	0.29	26	j	+0.34	0.18
1	m	-1.15	0.29	7	ɘ	+0.81	0.16
13	w	-1.10	0.28	14	ʒ	+0.99	0.16
16	f	-1.08	028	15	ɔ	+1.12	0.15
19	σ	-1.06	0.28	33	ƨ	+1.28	0.15
34	t	-0.90	0.26	12	ɟ	+1.46	0.15
31	r	-0.70	0.25	24	ɖ	+1.59	0.14
28	d	-0.54	0.23	32	ɒ	+1.62	0.14
17	i	-0.49	0.23	36	ə	+1.78	0.14
21	u	-0.35	0.22	11	ρ	+1.93	0.14
35	c	-0.21	0.21	4(hardest)	ɛ	+2.26	0.14
25	g	-0.11	0.20				

Note: Items are ordered from easiest (item 9, -2.06 logits) to hardest (item 4, +2.26 logits)

Table 6.7

Difficulties for 14 Final Items in Visual Discrimination for Numbers Scale

Item No	Item Letter	Difficulty	SE	Item No	Item Letter	Difficulty	SE
6(easiest)	1	-1.79	0.33	10	9	+0.69	0.20
17	1	-1.36	0.28	9	ə	+0.93	0.16
2	8	-1.08	0.25	18	ᔭ	+0.96	0.16
4	6	-0.81	0.23	5	ᒥ	+1.43	0.16
7	4	-0.79	0.23	13	ρ	+1.43	0.15
3	2	-0.38	0.23	11	ε	+1.53	0.15
19	5	-0.33	0.20	20	ε (hardest)	+1.78	0.15

Note: Items are ordered from easiest (item 6, -1.79 logits) to hardest (item 20, +1.78 logits)

Comments on the Non-Fitting Items Deleted from the Three scales

Eighteen items were deleted from the Visual Discrimination Upper Case Letters due to poor fit to the Rasch measurement model. Usually the main reason for non-fit is poor agreement in regard to the item difficulty. For example, half of the medium ability students may say an item is easy and half say that it is hard, thus it does not fit the measurement model and is deleted. The 12 items deleted in Visual Discrimination of Upper Case Letters were: J, H, and the reversed letters C, B, F, S, R, Z, L, N, J, and D. One possible reason for the students' disagreement on the difficulty of these letters may be due to the font used in this assessment. It is also of particular interest that most of the letters deleted due to disagreement were the letters printed in the reversed orientation. A number of students verbalised the fact that they confused the reversed J and L with the correctly oriented letter L and J respectfully. A substantial number of students requested information assisting with identification of the reversed letter J, asking "what letter is this". In addition, other less obvious factors for the disagreement on the item difficulty may play a part in the complex perceptual task in this scale.

In Visual Discrimination of Lower Case Letters, five of the original 36 letters were deleted due to non-fit to the Rasch measurement model. The deleted letters were the reversed letters y, j, r, f, and b. It is again noticeable that all the letters where there was poor fit were the reversed letters. Except for the letter r, the font should not have affected the students' interpretation of these letters; however the orientation of the letters may have been the confusing factor. In addition, other less obvious factors for the disagreement on the item difficulty may play a part in the complex perceptual task in this scale.

Six of the original numbers were deleted in Visual Discrimination of Numbers due to non-fit to the Rasch measurement model. The numbers excluded from the analysis were 7, 3, 8 and the reversed numbers 5, 5, and 2. The first 8 in the assessment received good agreement among the students and was one of the easiest items, however when the 8 appeared the second time in the scale, there was disagreement among the student as to the difficulty of this item. This second number 8 was situated between two other numbers (3 and reversed 2) where there was poor agreement of difficulty on the second last line of the scale, thus the positioning of the items may have had an influencing factor on the students' response. Both of the reversed number 5's caused poor agreement on the difficulty of the item for students.

Inferences from the Measures of the Three Linear Rasch Scales

Linear scales were created that show good fits to the measurement model for the Visual Discrimination of Upper Case Letters, Visual Discrimination of Lower Case Letters and Visual Discrimination of Numbers. Valid inferences can now be made about the student measures for visual discrimination from these three linear scales. The bottom 19 student measures for Visual Discrimination Upper Case Letters have been taken because these students all scored 14/18 or less, meaning that they were the students who responded incorrectly to the last four letters including the reversed letters. These student measures are presented in Table 6.8.

Table 6.8:

Lowest 19 Student Measures Visual Discrimination Upper Case Letters

ID	Raw score	Location	SE	Residual
75	4	-1.32	0.58	2.31
37	7	-0.49	0.51	2.64
323	10	0.23	0.50	1.15
64	10	0.23	0.50	0.21
80	13	1.00	0.55	1.70
76	14	1.31	0.59	-0.84
74	14	1.31	0.59	1.34
42	14	1.31	0.59	-0.28
164	14	1.31	0.59	-0.02
324	14	1.31	0.59	0.29
62	14	1.31	0.59	-0.61
83	14	1.31	0.59	-0.55
27	14	1.31	0.59	0.72
72	14	1.31	0.59	-0.73
79	14	1.31	0.59	0.63
81	14	1.31	0.59	0.17
66	14	1.31	0.59	-0.64
209	14	1.31	0.59	0.20
5	14	1.31	0.59	-1.14

The child who scored four in Visual Discrimination of Upper Case Letters was only able to discriminate letters that were symmetrical around the vertical axis. Students who scored 10 had some difficulty discriminating asymmetrical letters as well as reversed upper case letters, whereas the students who scored 14 mainly found the reversed letters difficult to discriminate. Students scoring poorly in Visual

Discrimination of Upper Case Letters have difficulty discriminating when upper case letters are reversed and may need extra assistance to improve this skill.

The bottom 21 student measures for Visual Discrimination of Lower Case Letters have been taken because these students scored less than 19 out of 31, meaning that they were unable to discriminate the reversed lower case letters. These student measures are presented in Table 6.9. Students, who scored 10, were only able to correctly discriminate the easiest 10 items in the scale and had difficulty discriminating most of the lower case letters with only a body such as the c, a, r as well as the letters with a body and tail such as g, y, p. They were unable to discriminate a lower case letter when it was in the reversed orientation. The students scoring 17 correct had difficulty with the q, s, j and all the letters presented in the reversed orientation. These student measures identify students who may require assistance to improve their skill in discrimination of the lower case reversed letters. They may also be the students who reverse their letters in reading, spelling and or writing.

Table 6.9:

Lowest Student Measures Visual Discrimination Lower Case Letters

ID	Raw score	Location	SE	Residual
323	10	-0.97	0.43	4.05
203	10	-0.97	0.43	4.28
75	10	-0.97	0.43	4.28
164	11	-0.79	0.42	0.03
64	14	-0.28	0.41	3.89
200	17	0.22	0.42	1.33
205	17	0.22	0.42	-0.68
20	18	0.39	0.42	0.81
2	18	0.39	0.42	1.20
308	18	0.39	0.42	0.14
113	18	0.39	0.42	0.13
37	18	0.39	0.42	3.73
80	19	0.57	0.43	-0.26
82	19	0.57	0.43	-1.60
110	19	0.57	0.43	0.97
81	19	0.57	0.43	-2022
208	19	0.57	0.43	-0.50
209	19	0.57	0.43	1.17
307	19	0.57	0.43	0.34
83	19	0.57	0.43	-1.56
26	19	0.57	0.43	-0.54

The bottom 15 student measures for Visual Discrimination of Numbers have been chosen because these students scored less than eight out of fourteen, meaning that they were unable to identify or discriminate any of the reversed numbers in the scale. These student measures are presented in Table 6.10. Students who scored four out of 14 were only able to discriminate the symmetrical numbers and the number 6. Students scoring seven were unable to discriminate any of the reversed numbers and also had difficulty with the number '9'. The font may have affected the discriminatory ability of some of the numbers such as the '9'; however the font makes most of the numbers distinguishable in a standard hand written form.

Table 6.10:

Lowest Student Measures Visual Discrimination Numbers

ID	Raw score	Location	SE	Residual
151	4	-1.14	0.65	0.33
80	5	-0.75	0.63	-0.86
113	5	-0.75	0.63	0.03
208	6	-0.39	0.62	-0.51
58	6	-0.39	0.62	0.37
27	6	-0.39	0.62	2.40
57	6	-0.39	0.62	-0.28
51	6	-0.39	0.62	0.22
150	6	-0.39	0.62	-1019
81	7	-0.02	0.61	0.59
234	7	-0.02	0.61	0.91
78	7	-0.02	0.61	0.86
301	7	-0.02	0.61	0.74
200	7	-0.02	0.61	1.08
139	7	-0.02	0.61	-0.69

Summary of Findings

Linear scales were created for Visual Discrimination of Upper Case Letters, Visual Discrimination of Lower Case Letters and Visual Discrimination of Numbers using the RUMM2020 Program (Andrich et al., 2005). The reliability of the three scales was shown by:

1. Global item fit as well as person item fit to the measurement model;
2. Good Person Separation Indices indicating that the person measures were reasonably well, or acceptably well, separated in relation to the errors;
3. Good item-trait interaction chi-squares indicating the measurement of a unidimensional trait;

4. Targeting of items against the person measures was reasonable, but indicates the need for more difficult items in the scales for future use.

Valid inferences may be drawn from the scales as the scale data were shown to be reliable. Inferences are that the easiest letters and numbers for students to discriminate were the T, X, Y, k, h, b, 1 and 8, while the most difficult letters and numbers for students to discriminate were ꟼ, ꓘ, Ǝ, ɘ, ᑫ, ɛ,and the number Ɛ. For Visual Discrimination of Upper Case Letters, girls scored higher than boys, but this was not statistically significant. There was a statistical significant difference between private and public schools, with public schools scoring a higher mean average. Furthermore, there was as expected, a statistically significant difference in the performance of students as their age and grade increased, with younger students in lower grades scoring significantly lower than the older students in the higher grades. Students with the lowest scores were those that had most difficulty discriminating reversed upper case letters.

For Visual Discrimination of Lower Case Letters the girls scored a higher mean average than boys, but this was not statistically significant. Public schools also scored a higher mean value than private schools, but this was not statistically significant. The younger students in the lower grades scored a lower mean value than the older students in the higher grades and this was statistically significant. Students with the lowest scores had difficulty discriminating reversed lower case letters, lower case letters with a body and a tail as well as lower case letters with only a body.

In Visual Discrimination of Numbers, the girls scored a statistically higher mean average than the boys. Although public schools had a higher mean average than private schools, this was not statistically significant. Mean values increased with age from the youngest students (four years old) to the oldest students (10 plus years old) with a statistically significant difference. The mean values increased by grade from Pre-primary to Grade 3 with a statistically significant difference. Students with the lowest measures had difficulty discriminating reversed numbers as well as the number ‘9’.

The next chapter presents a summary of the Rasch linear analysis for Spatial Orientation Upper Case Letter, Lower Case Letter and Number Pairs and Letter and

Number Sequencing. Inferences that can be validly made from these summaries will also be explained.

CHAPTER SEVEN

DATA ANALYSIS (PART TWO)

RASCH MEASUREMENT OF SPATIAL ORIENTATION LETTER AND NUMBER PAIRS AND LETTER AND NUMBER SEQUENCING

This chapter presents part two of the Rasch data analysis. This chapter includes Spatial Orientation of Letters and Numbers as well as Letter and Number Sequencing as these scales relate to the position of letters and numbers in relation to each other on the page (spatial position), whereas the other scales relate to other visual perceptual concepts. This chapter describes the measurement results in terms of Rasch measurement fit statistics in summary form to avoid unnecessary repetition of output similar to that in Chapter Six. It includes global item and person fit to the measurement model, dimensionality, person separation indices, distribution of item-person interactions, and discrimination. Some discussion is included of the non-fitting items as well as good fitting items and the person-item threshold distribution (targeting). This is followed by mean Rasch measures by group and final items for the Spatial Orientation and Sequencing Scales discussion. Finally, inferences drawn from the linear Rasch measurement data analysis and the summary of the results are presented.

Initial Rasch Analysis

For Spatial Orientation and Letter and Number Sequencing

An initial Rasch analysis was performed on the original items for Spatial Orientation Letter and Number Pairs (37 items), and Letter and Number Sequencing (42 items) where each item was scored in one of two categories (wrong scored zero and correct scored one). Ten of the initial 37 items of Spatial Orientation Letter and Number Pairs were deleted due to item misfit statistics. The remaining 27 items were found to have a reasonable fit to the measurement model for the 324 persons included in this study. For Letter and Number Sequencing, six of the initial 42 items were deleted due to item misfit statistics. The remaining 36 items displayed a good fit to the measurement model.

Final Rasch Analysis Results

The following material shows the results for the final Rasch analysis for Spatial Orientation Letter and Number Pairs (27 items), and Letter and Number Sequencing (36 items).

Summary of Fit Statistics

The RUMM2020 program estimates of Standardised Fit Residual statistics are presented in Table 7.1. These item-person interaction statistics determine whether the item estimations contribute meaningfully to the measurement of one construct (despite the combination of letters and numbers in one scale) and whether there is a consistent person-item pattern of responses. The Standard Fit Residuals of these two measures have a distribution with a mean near zero and a standard deviation near one, indicating that the data fit the measurement model. This also means that there is a good pattern of person and item responses consistent with a Rasch measurement model.

Dimensionality

For Spatial Orientation Letter and Number Pairs, there was an item-trait interaction chi-square of 77.98 with df=0.96 and a probability of 0.57. This means that the scale is constructed with excellent agreement amongst the students about the linear progressive difficulty of the items. The item-trait interaction chi-square for Letter and Number Sequencing was 124.95 with df=0.97 and a probability of 0.13, showing acceptable agreement amongst the students about the linear progressive difficulty of the items along the scale.

Table 7.1:

Global Item and Student Fit Residual Statistics (N=324) for Spatial Orientation Letter and Number Pairs (I=27) and Letter and Number Sequencing (I=36)

	ITEMS		PERSONS	
	Location	Fit Residual	Location	Fit Residual
	Spatial Orientation of Letter and Number Pairs (I=27)			
Mean	0.00	-0.57	2.06	-0.15
Standard Dev.	0.52	1.17	1.33	0.76
	Letter and Number Sequencing (I=36)			
Mean	0.00	-0.74	2.05	-0.39
Standard Dev.	0.86	1.24	2.27	0.90

Comment on Table 7.1:
Fit residuals have a mean near zero and a standard deviation near one when the data fit the measurement model (as is the case here). This reflects good consistency of item and student scoring patterns.

Person Separation Index

The Person Separation Index for Spatial Orientation Letter and Number Pairs is 0.84 (Cronbach's Alpha Coefficient of Reliability was 0.88), while the Person Separation Index for Letter and Number Sequencing is 0.94 with a Cronbach's Alpha Coefficient of Reliability of 0.97. For a good measure, it is desirable that this index should be 0.9 or greater, as it is an indicator that the student measures are separated by more than their standard errors. Based on this index, the Spatial Orientation Letters and Number Pairs scale demonstrates good separation, and the Letter and Number Sequencing Scale demonstrates an excellent separation.

Individual Item Fit

Items are ordered by calibrated values to evaluate their fit to the measurement model. All the items in Spatial Orientation Letter and Number Pairs fit the measurement model with probabilities greater than p=0.02 (see Table 7.2). Standardised residuals should fall within the range of -2 and +2. Table 7.2 shows that all items for Spatial Orientation Letter and Number Pairs have acceptable residuals except for item 13 and item 34. For Letter and Number Sequencing, all the items fit the measurement model with probabilities greater than p=0.03 (see Table 7.3), but some of the residuals are a little outside what might be considered good limits.

Table 7.2:

Individual Item Fit Statistics for Spatial Orientation letter and Number Pairs

Item	Location	SE	Residual	DegFree	ChiSq	DegFree	Prob
14	-0.97	0.22	-0.58	245.56	5.55	3	0.14
3	-0.94	0.21	+0.52	245.56	2.47	3	0.48
13	-0.66	0.20	-2.27	245.56	4.81	3	0.19
4	-0.57	0.19	-0.90	245.56	1.53	3	0.68
6	-0.50	0.19	-1.55	245.56	5.72	3	0.13
12	-0.45	0.19	-1.31	245.56	3.09	3	0.38
31	-0.40	0.18	+0.08	245.56	1.04	3	0.79
22	-0.20	0.18	-1.79	245.56	5.25	3	0.15
10	-0.15	0.17	-0.47	245.56	1.46	3	0.69
1	-0.13	0.17	+1.02	245.56	4.27	3	0.23
26	-0.13	0.17	-1.63	245.56	1.92	3	0.59
19	-0.11	0.17	-1.52	245.56	1.88	3	0.60
35	-0.10	0.17	+0.05	245.56	0.26	3	0.97
11	-0.03	0.17	-0.75	245.56	3.29	3	0.35
28	0.00	0.17	-1.07	245.56	2.25	3	0.52
5	0.04	0.17	-0.13	245.56	1.84	3	0.61
21	0.12	0.16	-1.71	245.56	5.49	3	0.14
27	0.14	0.16	-0.79	245.56	1.19	3	0.76
34	0.24	0.16	-2.81	245.56	7.32	3	0.06
32	0.31	0.16	-1.38	245.56	3.05	3	0.38
15	0.43	0.16	-1.11	245.56	3.12	3	0.37
36	0.46	0.16	+0.81	245.56	0.92	3	0.82
16	0.48	0.15	+0.98	245.56	0.49	3	0.92
29	0.51	0.15	-0.09	245.56	0.59	3	0.90
33	0.58	0.15	+1.76	245.56	2.12	3	0.55
17	0.59	0.15	-0.50	245.56	2.63	3	0.45
18	1.43	0.14	+1.71	245.56	4.44	3	0.22

Notes on Table 7.2 and 7.3:

1. Location refers to the difficulty of the item on the linear scale.
2. SE means Standard Error, and refers to the degree of uncertainty in a value.
3. Residual represents the difference between the expected value of an item, calculated according to the Rash measurement model and the actual value.
4. DegFree stands for degrees of freedom, and refers to the number of scores in a distribution that are free to change without changing the mean distribution.
5. ChSq stands for Chi-square
6. Prob relates to the probability based on the Chi-square and refers to the levels of certainty to which an item fits the measurement model.

Table 7.3:

Individual Item Fit Statistics for Letter and Number Sequencing

Item	Location	SE	Residual	DegFree	ChiSq	DegFree	Prob
4	-1.53	0.31	-1.12	241.11	1.57	3	0.67
3	-1.51	0.31	-1.23	241.11	2.02	3	0.57
9	-1.20	0.28	-0.67	241.11	1.52	3	0.68
8	-1.12	0.28	-0.72	241.11	0.39	3	0.94
2	-1.07	0.27	-1.19	241.11	5.10	3	0.16
5	-0.85	0.26	-0.37	241.11	2.78	3	0.43
1	-0.66	0.25	0.83	241.11	4.10	3	0.25
12	-0.61	0.24	-0.56	241.11	2.27	3	0.52
7	-0.59	0.24	-1.20	241.11	2.88	3	0.41
6	-0.57	0.24	-0.49	241.11	2.29	3	0.51
40	-0.45	0.23	0.20	241.11	3.50	3	0.32
14	-0.40	0.23	-2.29	241.11	9.09	3	0.03
37	-0.35	0.23	0.84	241.11	0.83	3	0.84
27	-0.30	0.22	-2.57	241.11	7.40	3	0.06
33	-0.27	0.22	0.89	241.11	0.99	3	0.80
15	-0.12	0.21	-0.89	241.11	2.47	3	0.48
24	-0.11	0.21	-2.32	241.11	9.19	3	0.03
21	-0.09	0.21	-3.22	241.11	7.21	3	0.07
36	-0.09	0.21	0.66	241.11	2.85	3	0.41
10	-0.09	0.21	0.78	241.11	6.04	3	0.11
32	-0.04	0.21	-1.97	241.11	3.83	3	0.28
19	0.04	0.21	-2.09	241.11	4.04	3	0.26
11	0.06	0.21	0.90	241.11	2.44	3	0.49
38	0.09	0.20	-0.65	241.11	2.56	3	0.47
31	0.22	0.19	-2.06	241.11	3.86	3	0.28
23	0.31	0.19	-2.38	241.11	4.01	3	0.26
20	0.62	0.18	-1.40	241.11	2.25	3	0.52
34	0.70	0.18	0.94	241.11	3.88	3	0.27
17	0.79	0.18	-2.45	241.11	5.01	3	0.17
41	0.83	0.17	-0.61	241.11	3.93	3	0.27
16	1.23	0.16	-0.88	241.11	4.82	3	0.19
22	1.23	0.16	-0.95	241.11	3.44	3	0.33
35	1.24	0.16	2.06	241.11	2.27	3	0.52
26	1.36	0.16	-0.25	241.11	2.12	3	0.55
30	1.37	0.16	-0.12	241.11	0.97	3	0.81
28	1.97	0.15	-0.17	241.11	1.07	3	0.78

Targeting

The student-measure item-difficulty or targeting graph for Spatial Orientation Letter and Number Pairs (see Figure 7.1), shows that the student measures cover a range of about -1.8 to +4.0 logits and the item difficulties cover a range of about -1.0 to +1.5 logits. From the graph it can be seen that many students (about 200) were able to answer all the items correctly, while a few students (about five) were not able to answer any of the items correctly. This suggests that the targeting of the items needs to be improved in any future use of the scale by adding in some harder items to ‘cover’ the students with the higher measures.

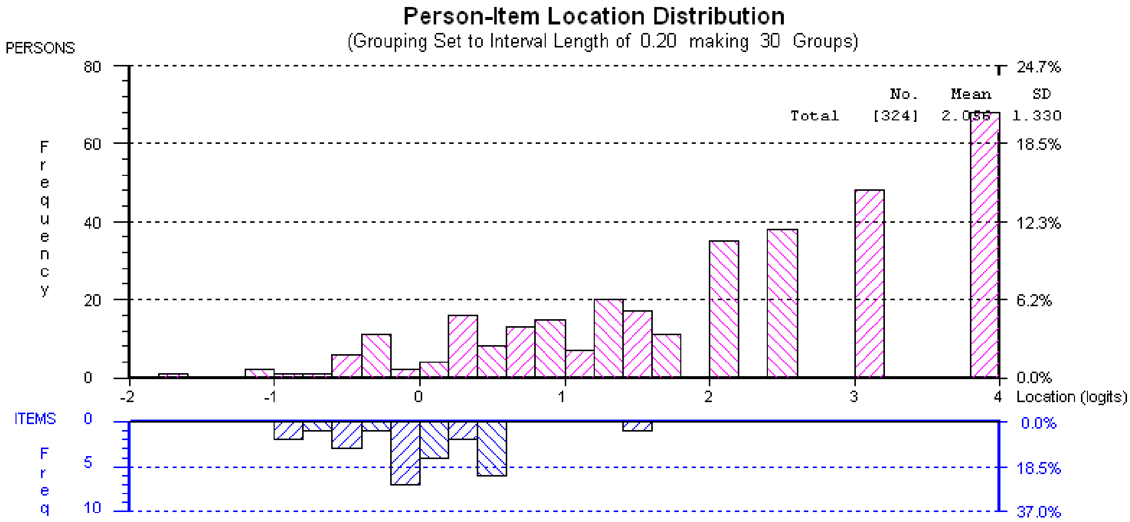


Figure 7.1: Targeting Graph for Spatial Orientation Letter and Number Pairs
Note: Student measures are on the upper side in logits. Item difficulties are on the lower side of the same scale in logits. Many students (about 200) answered the items correctly.

For Letter and Number Sequencing (see Figure 7.2), the targeting graph shows that the student measures cover a range of about -4.4 to +4.3 logits and the item difficulties cover a range of about -1.7 to +2.0 logits. From the graph it can be seen that many students (about 220) were able to answer the items correctly, while some students (about 30) were unable to answer any items correctly. The targeting of the items needs to be improved in any future use of the scale by adding in some harder items to ‘cover’ the students with the higher measures.

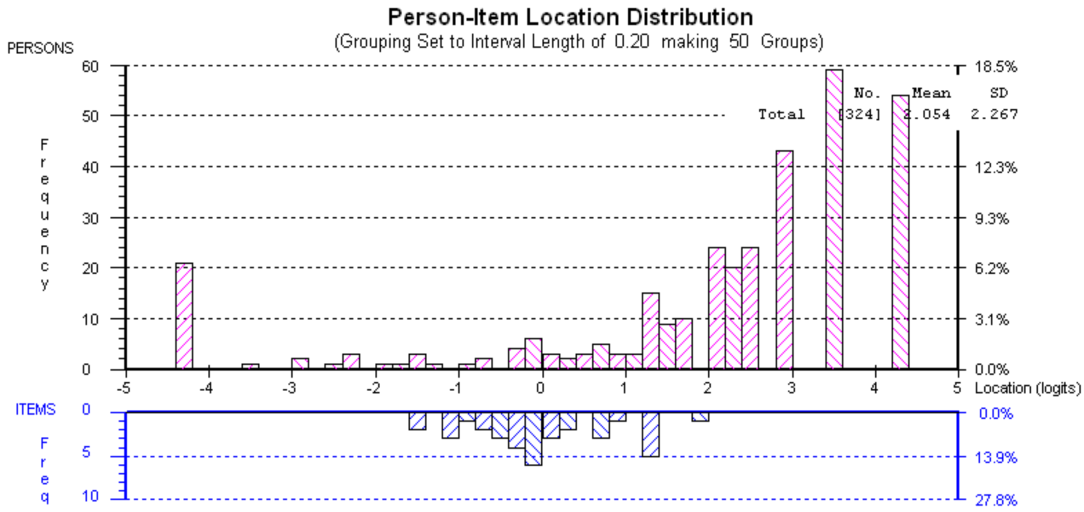


Figure 7.2: Targeting Graph for Letter and Number Sequencing
Note: Student measures are on the upper side in logits. Item difficulties are on the lower side of the same scale in logits. Many students (about 220) answered the items correctly.

Discrimination

Item Characteristic Curves examine the relationship between the expected response and the observed score for each item. These curves display how well the item discriminates between different groups of mean student measures (locations). An example of one item characteristic curve for each construct is presented. Figure 7.3 shows the Item Characteristic Curve for Item 31 Spatial Orientation of Letter and Number Pairs. This curve shows that the item discriminates well for students with different measures. The Item Characteristic Curves for all the other items were checked and found to be satisfactory (but are not reported here to avoid unnecessary repetition).

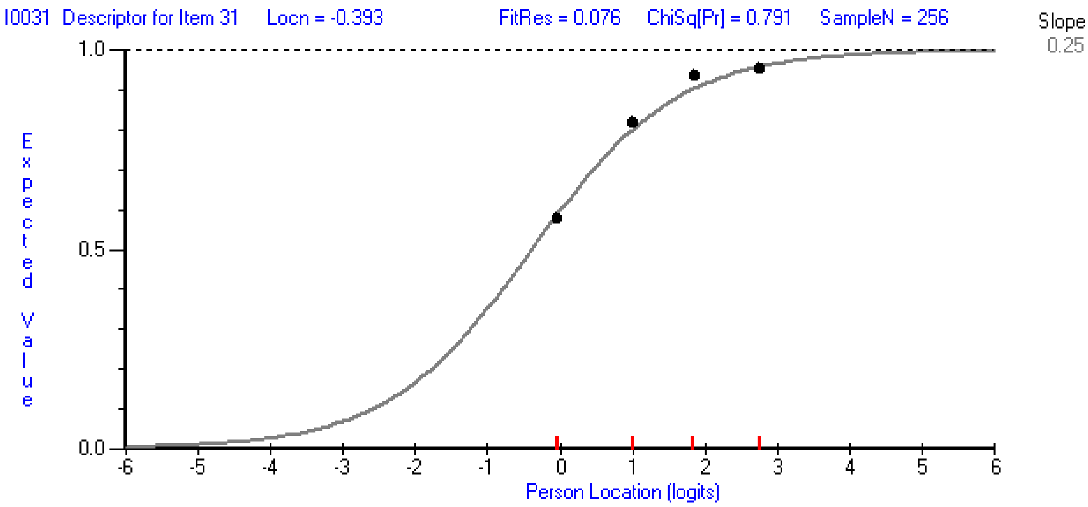


Figure 7.3: Item Characteristic Curve: Item 31 – Spatial Orientation of Letter and Number Pairs

Item Characteristic Curves for each item in Letter and Number Sequencing were also found to discriminate well for groups of students with different measures. Figure 7.4 presents an example of an Item Characteristic Curve for Item 1 in Letter and Number Sequencing. The Item Characteristic Curves for all the other items were checked and found to be satisfactory (but are not reported here to avoid repetition).

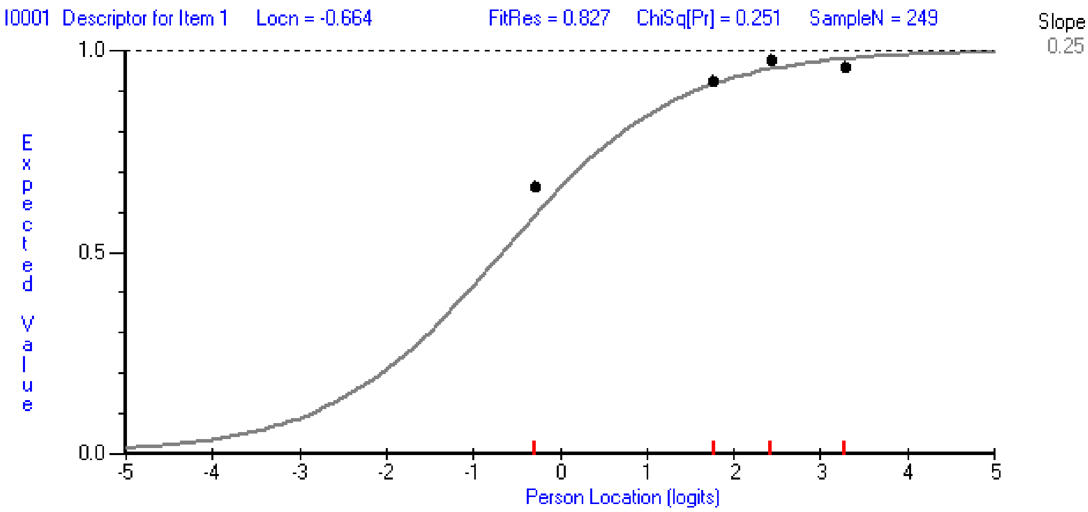


Figure 7.4: Item Characteristic Curve: Item 1 – Letter and Number Sequencing

Consistency of Use of Scoring Categories

The RUMM2020 program produces graphs of the scoring categories for each item. The Scoring Category Curves show the relationship between the probability of scoring in each category (zero for wrong and one for right) on each item. Figure 7.5 is the Scoring Category Curve for item 1 of Spatial Orientation of Letter and Number Pairs. This figure shows that the scoring was done logically and consistently. When students have low measures on item 1, then they have a high probability of obtaining a zero score (answer incorrectly) and, when they have a high measure, they have a high probability of scoring 1 (answer correctly). The Scoring Category Curves for all the other items were checked and they were also satisfactory. Figure 7.6 shows the Scoring Category Curve for Item 1 of Letter and Number Sequencing. This figure confirms that the scoring was done logically and consistently for this item. The Scoring Category Curves for all the items of Letter and Number Sequencing were checked and they were also found to be satisfactory, but they are not presented here to avoid unnecessary repetition.

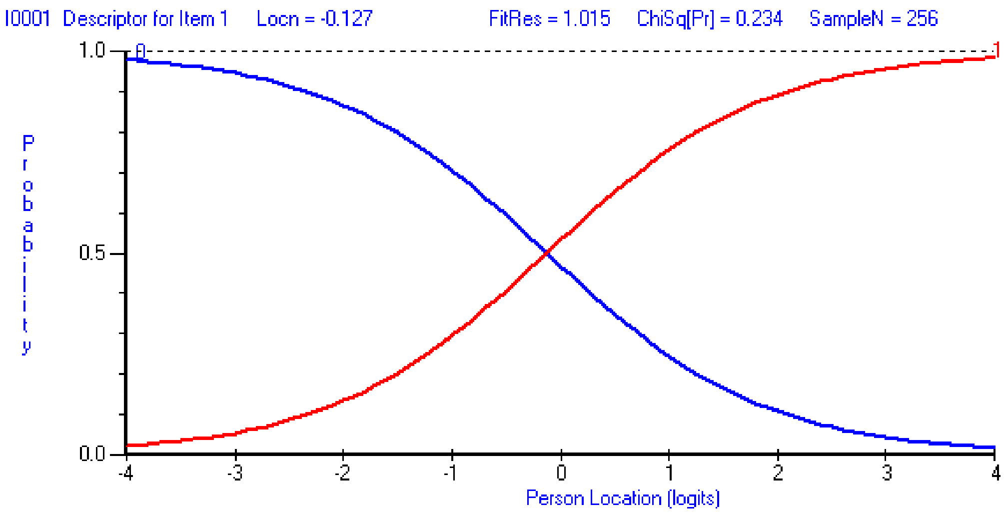


Figure 7.5: Scoring Category Curve: Item1 – Spatial Orientation Letter and Number Pairs

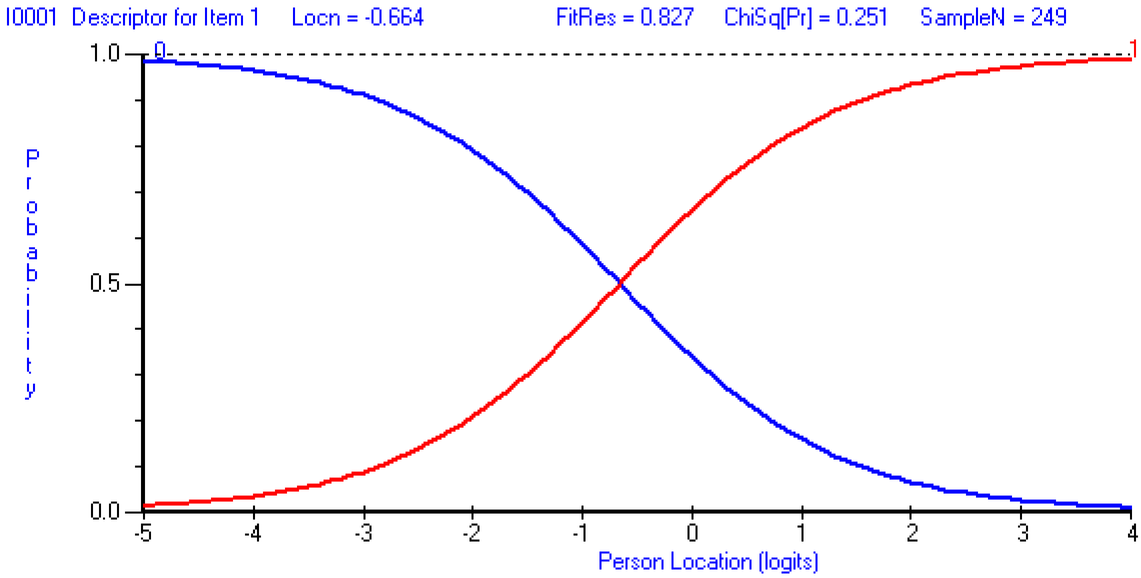


Figure 7.6: Scoring Category Curve: Item1 – Letter and Number Sequencing

Characteristics of the Sample (SOLNP)

The measures for Spatial Orientation of Letter and Number Pairs (SOLNP) were displayed in a graphical format separated by gender (Figure 7.7), type of school (Figure 7.8), age (Figure 7.9), grade (Figure 7.10) and whether intervention had been received (Figure 7.11). The mean differences were then tested for statistical significance using t-tests. Females have a higher mean measure than males for Spatial Orientation of Letter and Number Pairs which is statistically, significantly different (t=2.96, df=322, p=0.000). Public school students have a higher mean measure than private school students for Spatial Orientation of Letter and Number Pairs but this is not statistically, significantly different (t=1.53, df=322, p=0.08). As would be expected, the mean measures generally increased by age from four years of age (lowest) to nine years of age (highest) and this was statistically, significantly different in favour of the older students (t=9.86, df=66, p=0.000). Again, as expected, the mean measures generally increased by grade from Pre-primary (lowest) to Year 3 (highest) and this was statistically, significantly different (t=11.6, df=127, p=0.000). While the mean measures for no intervention were higher than for intervention, this was not statistically, significantly different (t=1.93, df=322, p=0.025).

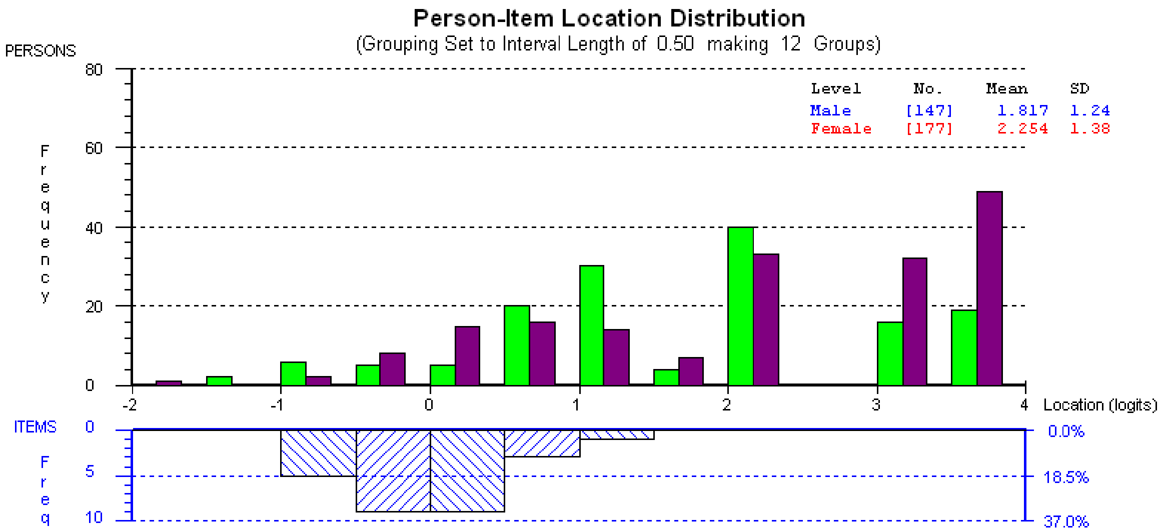


Figure 7.7: Target Graph by Gender for Spatial Orientation of Letter and Number Pairs

Note: There is a colour error in the RUMM program. Purple represents the females (not red) and green represents the males (not blue).

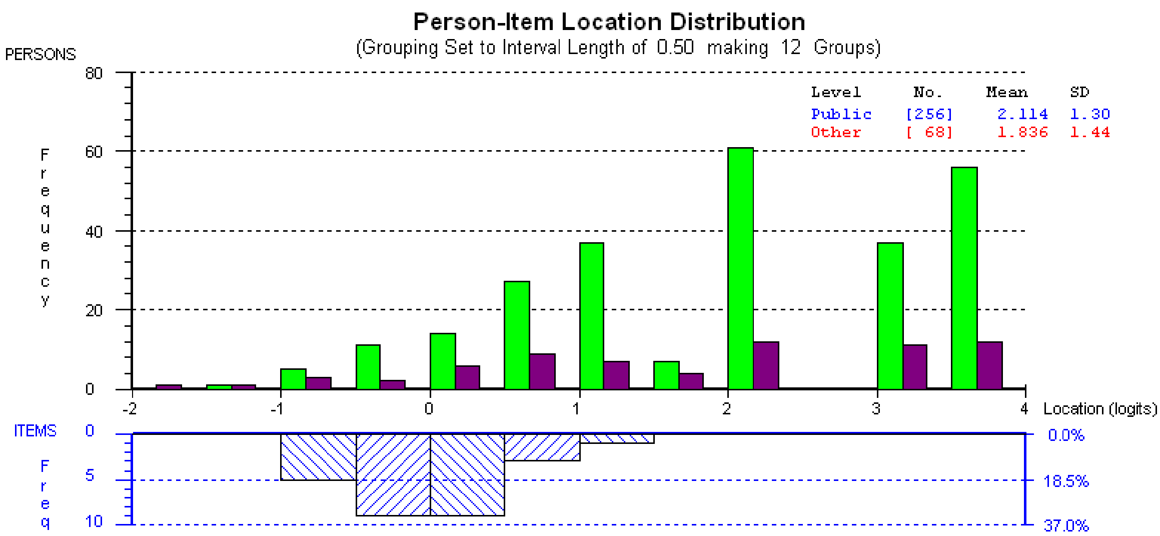


Figure 7.8: Target Graph by Type of School for Spatial Orientation of Letter and Number Pairs

Note: There is a colour error in the RUMM program. Purple represents other schools (not red) and green represents the public schools (not blue).

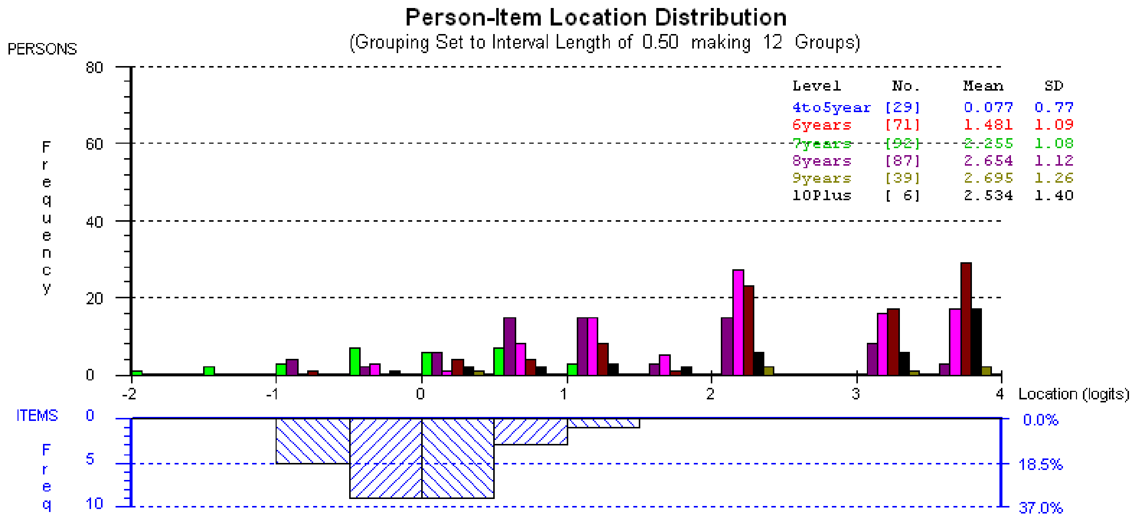


Figure 7.9: Target Graph by Age for Spatial Orientation of Letter and Number Pairs

Note: There is a colour error in the RUMM program. Four and five year olds are represented by green (not blue), six year olds are represented by Purple (not red), seven year olds are represented by pink (not green), eight year olds are represented by maroon (not purple), nine year olds are represented by black (not brown-green) and ten years and above are represented by brown-green (not black).

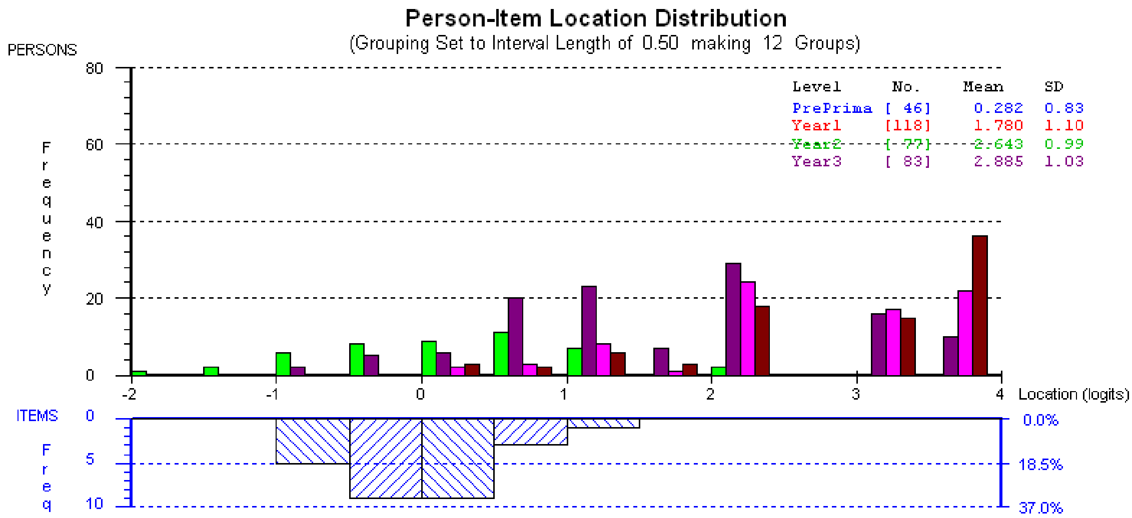


Figure 7.10: Target Graph by School Year for Spatial Orientation of Letter and Number Pairs

Note: There is a colour error in the RUMM program. Pre-primary is represented by green (not blue), Year 1 is represented by purple (not red), Year 2 is represented by pink (not green), and Year 3 is represented by maroon (not purple).

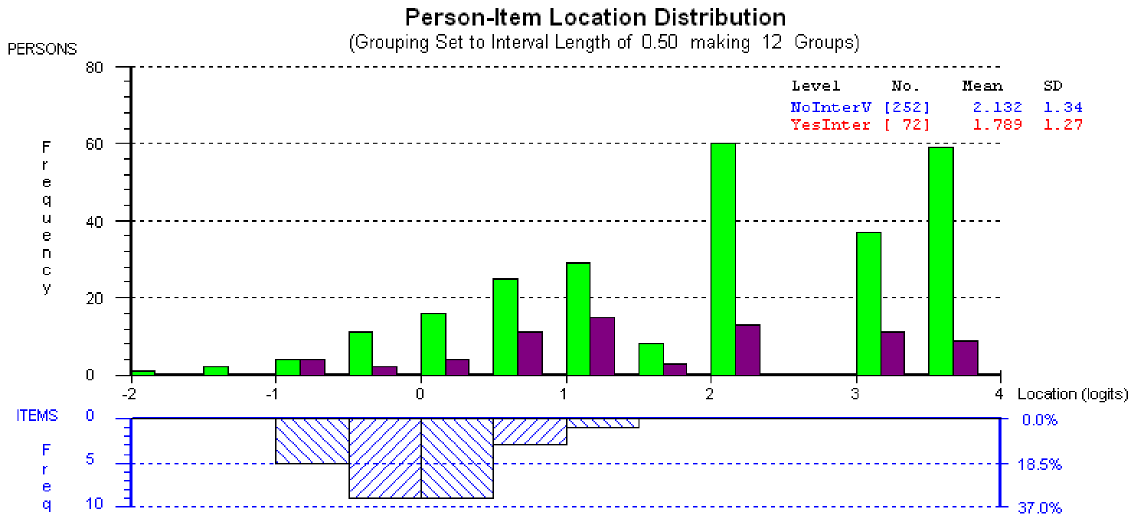


Figure 7.11: Target Graph by Intervention for Spatial Orientation of Letter and Number Pairs

Note: There is a colour error in the RUMM program. Green represents no intervention and purple intervention.

The graphical data for Letter and Number Sequencing was checked in the RUMM computer program but is not produced here to avoid too much repetition but the graphs are similar to those produced for Spatial Orientation of Letter and Number Pairs. Females have a higher mean measure than males for Letter and Number Sequencing but this is not statistically, significantly different (t=1.18, df=322, p=0.18). Public school students have a higher mean measure than private school students for Letter and Number Sequencing and this is not statistically, significantly different (t=0.84, df=322, p=0.20). As would be expected, the mean measures generally increased by age from four years old (lowest) to ten year old or older (highest) and this was statistically, significantly different in favour of the older student (t=7.86, df=66, p=0.000). Again, as expected, the mean measures generally increased by grade from Pre-primary (lowest) to Year 3 (highest) and this was statistically, significantly different (t=13.3, df=127, p=0.000). While the mean measure for no intervention was higher than for intervention, this was not statistically significantly different (t=0.37, df=322, p=0.38).

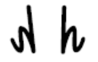
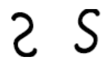
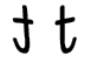
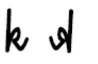
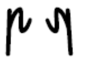
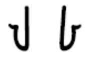
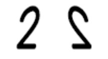
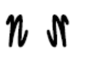
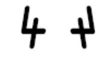
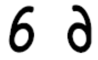
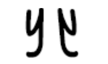
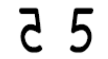
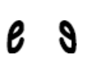
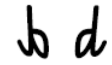
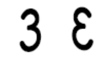
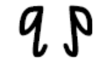
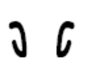
Final Items for the Two Spatial Scales

The final 27 items and their difficulties are presented, in order from easiest to hardest, in Table 7.4 for Spatial Orientation of Letter and Number Pairs. Using the Rasch Measurement Model allowed the linear presentation of item difficulties in a mixed number and letter scale. The students found it easy to discriminate the longer lower case letters, for example the h, k, and b. They found it moderately easy to discriminate upper case letter pairs that had an upright line on the left of the letter (e.g. K, F) and the number 7, moderately difficult to discriminate number pairs with sharper angles (e.g. 2, 4, 5) and most difficult to discriminate lower case letter pairs and number pairs that were curved in the Victorian Cursive font (e.g.3**,** z, q).

In the Letter and Number Sequencing scale (see Table 7.5 for the 36 item difficulties ordered from easy to hard), students found it easy to discriminate number sequences, such as 273/372 and 378/387, and moderately easy to discriminate letter and number sequences when given a choice of five combinations to choose from (e.g. ab | ab ba ad ab) or when the letters that are out of sequence are not similar in form (e.g. play/payl). Sequences that were not changed (e.g.1543/1543, bdhtf/bdhtf) or where the change was in the middle of the sequence (e.g. was/saw, 9834/9843) were moderately difficult to discriminate, while sequences where two sequential letters consisting only of a body were swapped (e.g. jump/jmup, soac/saoc), were the most difficult to discriminate.

Table 7.4:

Difficulties for 27 Final Items in Spatial Orientation of Letter and Number Pairs Scale

Item No	Item	Difficulty	SE	Item No	Item	Difficulty	SE
14 (easiest)		-0.97	0.22	28		+0.00	0.17
3		-0.94	0.21	5		+0.04	0.17
13		-0.65	0.20	21		+0.12	0.16
4		-0.57	0.19	27		+0.14	0.16
6		-0.50	0.19	34		+0.24	0.16
12		-0.45	0.19	32		+0.32	0.16
31		-0.39	0.18	15		+0.43	0.16
22		-0.20	0.18	36		+0.46	0.16
10		-0.15	0.17	16		+0.48	0.15
26		-0.13	0.17	29		+0.51	0.15
19		-0.11	0.17	33		+0.58	0.15
35		-0.10	0.17	17		+0.59	0.15
11		-0.03	0.17	18		+1.43	0.14

Note: Items are ordered from easiest (item 14, -0.97 logits) to hardest (item 18, +1.43 logits)

Table 7.5:

Difficulties for 36 Final Items in the Letter and Number Sequencing Scale by Order

Item No	Item	Difficulty	SE	Item No	Item	Difficulty	SE
4 (easiest)	273/372	-1.53	0.31	36	ts/5 choices	-0.09	0.21
3	378/387	-1.52	0.31	10	1543/1543	-0.04	0.21
9	495/594	-1.20	0.28	32	bdhtf/bdhtf	+0.04	0.21
8	251/251	-1.12	0.28	19	was/saw	+0.06	0.21
2	22/22	-1.07	0.27	11	9834/9843	+0.09	0.21
5	1372/1732	-0.84	0.26	38	pjb/5 choices	+0.22	0.20
1	21/12	-0.66	0.26	31	soua/soua	+0.31	0.20
12	83257/83257	-0.61	024	23	on/no	+0.62	0.19
7	56/65	-0.59	0.24	20	fgpt/fgpt	+0.69	0.18
6	6761/6761	-0.57	0.24	34	dp/5 choices	+0.79	0.18
40	54/five options	-0.45	0.23	17	like/liek	+0.83	0.18
14	play/payl	-0.40	0.23	41	63/5 choices	+1.23	0.17
37	nac/5 choices	-0.35	0.23	16	found/fuond	+1.23	0.16
27	hers/hers	-0.30	0.22	22	hfklt/hfhlt	+1.24	0.16
33	ab/5 choices	-0.27	0.22	35	fr/5 choices	+1.24	0.16
15	get/gef	-0.12	0.21	26	jump/jmup	+1.36	0.16
24	stop/stop	-0.11	0.21	30	soac/saoc	+1.37	0.16
21	pqbd/qpdb	-0.09	0.21	28	laugh/laugh	+1.97	0.15

Note: Items are ordered from easiest (item 4, -1.53 logits) to hardest (item 28, +1.97 logits)

Comments on the Non-Fitting Items Deleted from the Two Scales

Ten items were deleted from the Spatial Orientation of Letter and Number Pairs Scale due to poor fit to the Rasch measurement model. Usually the main reason for non-fit is poor agreement in regard to the item difficulty. For example, half of the high ability students may say an item is easy and half say that it is difficult, thus it does not fit the measurement model and is deleted. The 10 items deleted in Spatial Orientation of Letter and Number Pairs were f, j, s, g, L, R, G, Z, N, and 9. The students may have disagreed on these letters due to the font used in this assessment, or other less obvious factors which may play a part in this complex perceptual task. It is also of particular interest that most of the letter and number pairs deleted due to disagreement were the commonly confused letters, thus, students tending towards difficulty with spatial orientation would find them difficult, while students with a good concept of spatial orientation would find them easy when printed in the reversed orientation.

In Letter and Number Sequencing, six of the original 42 items were deleted due to non-fit to the Rasch measurement model. Three of the deleted sequences consisted of comparisons of the same sequence such as do/do and but/but. One sequence was a familiar word (dog/god) and two deleted sequences consisted of number sequences where the student had a choice of five possible responses (e.g. 29 |Ƨ9 92 2P 29 Ƨ9). In this scale, the font should not have affected the students' interpretation of the sequences as they were comparing sequences produced in the same font. However, as the task requires complex processes of comparison, other less obvious factors, such as short term memory may be playing a part in the students' disagreement of the difficulty of the items.

Inferences from the Measures of the Two Linear Rasch Scales

Linear scales were created that show good fits to the measurement model for the Spatial Orientation of Letter and Number Pairs and Letter and Number Sequences. Valid inferences can now be made about the student measures for spatial orientation from these two linear scales. The bottom 24 student measures for Spatial Orientation of Letter and Number Pairs have been taken because these students all scored 13/27 or less, meaning that they were the students who responded incorrectly to half of the lower case letter pairs, most of the upper case letter pairs as well as most of the numbers. These student measures are presented in Table 7.6.

Table 7.6:

Lowest 24 Student Measures Spatial Orientation of Letter and Number Pairs

ID	Raw score	Location	SE	Residual
324	4	-1.74	0.54	0.37
5	7	-1.07	0.45	0.67
151	7	-1.07	0.45	-0.11
200	8	-0.88	0.43	1.03
164	9	-0.71	0.42	-0.19
229	10	-0.55	0.41	0.36
323	10	-0.55	0.41	-0.78
84	10	-0.55	0.41	0.25
27	10	-0.55	0.41	-0.14
156	10	-0.55	0.41	0.81
80	10	-0.55	0.41	0.41
167	11	-0.39	0.40	1.67
203	11	-0.39	0.40	0.78
79	11	-0.39	0.40	0.78
18	11	-0.39	0.40	0.57
66	12	-0.23	0.40	1.23
166	12	-0.23	0.40	1.58
119	12	-0.23	0.40	2.40
205	12	-0.23	0.40	1.60
317	12	-0.23	0.40	0.68
303	12	-0.23	0.40	-1.74
81	12	-0.23	0.40	1.33
76	13	-0.08	0.40	-1.29
103	13	-0.08	0.40	0.38

The student who scored four in Spatial Orientation of Letter and Number Pairs was only able to identify lower case letters when presented in pairs. Students who scored 10 had some difficulty discriminating upper case letter pairs as well as number pairs, whereas the students who scored 13 mainly found the number pairs where the number had a sharp angle and curved letter pairs difficult to identify. Students scoring poorly in Spatial Orientation of Letter and Number Pairs have difficulty discriminating which orientation or direction a letter or number should face and may need extra assistance to improve this skill.

The bottom 35 student measures for Letter and Number Sequences have been taken because these students scored less than 11 out of 36, meaning that they were only able to identify number sequences and unable to identify any letter sequences. These student measures are presented in Table 7.7. Students, who scored zero, were not able to correctly identify any items in the scale and had difficulty discriminating numbers as well as letters in sequences. The students scoring 4 correct were only able to identify number sequences of 3 numbers and had difficulty with all the letter sequences and the longer number sequences. These student measures identify students who may require assistance to improve their skill in sequencing letters and numbers as used in spelling and calculations.

Table 7.7:

Lowest 35 Student Measures for Letter and Number Sequencing

ID	Raw score	Location	SE	Residual
18	0	-4.28	1.22	
169	0	-4.28	1.22	
167	0	-4.28	1.22	
166	0	-4.28	1.22	
165	0	-4.28	1.22	
324	0	-4.28	1.22	
162	0	-4.28	1.22	
156	0	-4.28	1.22	
289	0	-4.28	1.22	
37	0	-4.28	1.22	
163	0	-4.28	1.22	
12	0	-4.28	1.22	
8	0	-4.28	1.22	
7	0	-4.28	1.22	
6	0	-4.28	1.22	
5	0	-4.28	1.22	
4	0	-4.28	1.22	
2	0	-4.28	1.22	
153	0	-4.28	1.22	
323	0	-4.28	1.22	
161	0	-4.28	1.22	
203	1	-3.48	0.86	-0.25
164	2	-2.92	0.68	-0.08
150	2	-2.92	0.68	0.50
81	3	-2.53	0.59	-0.21
16	4	-2.24	0.53	0.06
151	4	-2.24	0.53	0.88
3	4	-2.24	0.53	0.46
80	5	-1.99	0.49	0.05
64	6	-1.77	0.46	-0.90
206	7	-1.58	0.44	1.15
66	7	-1.58	0.44	-0.76
26	7	-1.58	0.44	0.75
199	8	-1.40	0.42	1.45
27	11	-0.93	0.38	-0.30

Summary of Findings

Linear scales were created for Spatial Orientation of Letter and Number Pairs as well as for Letter and Number Sequences using the RUMM2020 Program (Andrich et al., 2005). The reliability of the two scales was shown by:

1. Good global item fit as well as person item fit to the measurement model;
2. Good Person Separation Indices indicating that the person measures were reasonably well, or acceptably well, separated in relation to the errors;
3. Good item-trait interaction chi-squares indicating the measurement of a uni-dimensional trait;
4. Good targeting of items against the person measures, but there is a need for more difficult items in the scales when they are used in the future.

Valid inferences may be drawn from the scales as the scale data were shown to be reliable. Inferences are that the easiest letter and number pairs for students to identify were the h, m, k, b, and p, while the most difficult letter and number pairs for students to identify were 3, q, and z. For Spatial Orientation of Letter and Number Pairs, girls scored higher than boys, but this was not statistically significant. There was no statistical significant difference between private and public schools or between the students who had intervention and those that did not have intervention. Furthermore, there was as expected, a statistically significant difference in the performance of students as their age and grade increased, with younger students in lower grades scoring significantly lower than the older students in the higher grades. Students with the lowest scores were those that had most difficulty identifying the correctly oriented letter or number in each letter and number pair.

For Letter and Number Sequencing, the girls scored a higher mean average than boys, but this was not statistically significant. Public schools also scored a higher mean value than private schools, but this was not statistically significant. The younger students in the lower grades scored a lower mean value than the older students in the higher grades and this was statistically significant. Students with the lowest scores had difficulty identifying the same or different sequences of letters and or numbers.

The next chapter presents a summary of the Rasch linear analysis for Form Constancy of Letters and Numbers, Letters in Words and Numbers in Calculations. Inferences that can be validly made from these summaries will also be explained.

CHAPTER EIGHT

DATA ANALYSIS (PART THREE)

RASCH MEASUREMENT OF FORM CONSTANCY OF LETTERS AND NUMBERS, LETTERS IN WORDS AND NUMBERS IN CALCULATIONS

Chapter Eight Data Analysis (Part Three) presents a Rasch analysis for three linear, unidimensional scales: (1) Form Constancy of Letters and Numbers, (2) Letters in Words, and (3) Numbers in Calculations. These three scales relate to form constancy and 'figure ground', whereas the scales in the previous Rasch analysis chapters related to other visual perceptual concepts. This chapter describes the measurement results in terms of Rasch measurement fit statistics including global item and person fit to the measurement model, dimensionality, person separation indices, distribution of item-person interactions, and discrimination. Some discussion is included of the non-fitting items, as well as good fitting items, and the person-item threshold distribution (targeting). This is followed by mean Rasch measures by group and final items for the Form Constancy and Figure Ground Scales discussion. Finally, inferences drawn from the linear Rasch measurement data analysis and the summary of the results are presented.

Initial Rasch Analysis

An initial Rasch analysis was performed on the original items for Form Constancy of Letters and Numbers (24 items), Letters in Words (41 items) and Numbers in Calculations (28 items) where each item was scored in one of two categories (incorrect answer scored zero and correct answer scored one). Six of the initial 24 items of Form Constancy of Letters and Numbers were deleted due to item misfit statistics. The remaining 18 items were found to have an excellent fit to the measurement model for the 324 persons included in this study. For Letters in Words, seven of the initial 41 items were deleted due to item misfit statistics. The remaining 34 items displayed an excellent fit to the measurement model. In the Numbers in Calculations section, 13 of the initial 28 items were removed because of item misfit statistics with the remaining 15 items found to have an excellent fit to the measurement model.

The Rasch analysis with the RUMM program does not indicate how to alter an item in order to make it fit the measurement model. In order to include, in a future measure, the deleted items which were initially considered conceptually valid, these would need to be changed and re-tested.

Final Rasch Analysis Results

The following material shows the results for the final Rasch analysis for the three scales: (1) Form Constancy of Letters and Numbers (18 items), and (2) the Figure Ground Scales of Letters in Words (34 items) and (3) Numbers in Calculations (15 items).

Summary of Fit Statistics

The RUMM2020 program estimates an item-person interaction which establishes the overall fit statistics that determine whether the item estimations contribute meaningfully to the measurement of one construct. This calculation thus examines the consistency with which students responses agree with the calculated difficulty of each item on the scale. The standardised fit residual statistics (see Table 8.1) have a distribution with a mean near zero and a standard deviation near one when the data fit the measurement model (Andrich, 1985), as is the case with these three measures. This means too that there is a good pattern of person and item responses consistent with a Rasch measurement model.

Dimensionality

For Form Constancy of Letters and Numbers, there was an item-trait interaction chi-square of 69.69 with df=0.94 and a probability of 0.07. This means that the scale is constructed with acceptable, but not ideal, agreement amongst the students about the linear progressive difficulty of the items. The item-trait interaction chi-square for Letters in Words was 117.59 with df=0.97 and a probability of 0.14, showing a similar acceptable agreement amongst the students about the linear progressive difficulty of the items along the scale. For Numbers in Calculations, the item-trait interaction chi-square was 58.83 with df=0.93 and a probability of 0.52 respectively, showing very good agreement amongst the students about the item difficulties along the scale. This means that the students agree as to which items are easy, which are of medium difficulty and which are hardest.

Table 8.1:

Global Item and Student Fit Residual Statistics (N=324) for Form Constancy of Letters and Numbers (I=18), Letters in Words (I=34) and Numbers in Calculations (I=15)

	ITEMS		PERSONS	
	Location	Fit Residual	Location	Fit Residual
	Form Constancy of Letters and Numbers (I=18)			
Mean	0.00	-0.45	+1.97	-0.20
Standard Dev.	0.65	0.89	2.06	0.75
	Letters in Words (I=34)			
Mean	0.00	-0.68	+2.00	-0.43
Standard Dev.	0.82	1.11	2.56	1.25
	Numbers in Calculations (I=15)			
Mean	0.00	-0.35	+1.29	-0.08
Standard Dev.	0.59	0.04	2.11	0.84

Comment on Table 8.1:
Fit residuals have a mean near zero and a standard deviation near one when the data fit the measurement model (as is the case here). This reflects good consistency of item and student scoring patterns.

Person Separation Index

The Person Separation Index is an estimate of the true score variance among the students and the estimated observed score variance using the estimates of their ability measures and the standard error of these measures (Andrich & van Schoubroeck, 1989). For Form Constancy of Letters and Numbers, Letters in Words and Numbers in Calculations, the Person Separation Indices are 0.94, 0.97 and 0.95 respectfully and the Cronbach Alpha Coefficient of Reliability for Numbers in Calculations was 0.98. For a good measure, it is desirable that the Person Separation Index should be 0.9 or greater, as it is an indicator that the student measures are separated by more than their standard errors. Based on this index, the Form Constancy of Letters and Numbers, Letters in Words and Numbers in Calculations scales demonstrate very good separation of measures in comparison to the errors of measurement.

Individual Item Fit

Items are ordered by calibrated values to evaluate their fit to the measurement model. The location of each item on the scale is the item difficulty in standard units, called logits (log odds of answering successfully). All the items in Form Constancy of

Letters and Numbers fit the measurement model with probabilities greater than p=0.03 (see Table 8.2). The residuals shown in Table 8.2 represent the difference between the observed responses and the expected responses calculated from the Rasch measurement parameters. Standardised residuals should fall within the range of -2 and +2. Table 8.2 shows that all items for Form Constancy of Letters and Numbers have acceptable residuals except for item 14.

Table 8.2:

Individual Item Fit Statistics for Form Constancy of Letters and Numbers

Item	Location	SE	Residual	DegFree	ChiSq	DegFree	Prob
18	-0.93	0.26	0.49	143.56	9.11	3	0.03
1	-0.72	0.25	-0.61	143.56	1.35	3	0.72
23	-0.70	0.25	+0.08	143.56	4.50	3	0.21
21	-0.63	0.24	-0.36	143.56	1.31	3	0.73
19	-0.50	0.24	+0.86	143.56	4.53	3	0.21
20	-0.40	0.23	+0.74	143.56	6.23	3	0.10
5	-0.33	0.23	-0.08	143.56	0.77	3	0.86
2	-0.33	0.23	-0.67	143.56	1.97	3	0.58
3	-0.26	0.23	-0.49	143.56	5.09	3	0.17
8	-0.12	0.23	-1.01	143.56	8.32	3	0.04
14	+0.10	0.22	-2.41	143.56	6.24	3	0.10
13	+0.28	0.21	-0.71	143.56	7.18	3	0.07
16	+0.29	0.21	-1.65	143.56	3.81	3	0.28
11	+0.51	0.21	+0.22	143.56	1.42	3	0.70
17	+0.70	0.20	-1.46	143.56	2.13	3	0.55
9	+0.71	0.20	+0.26	143.56	0.98	3	0.81
7	+0.93	0.20	-1.58	143.56	3.43	3	0.33
4	+1.39	0.19	-0.03	143.56	1.32	3	0.70

Notes on Table 8.2, 8.3 and 8.4:

1. Location refers to the difficulty of the item on the linear scale.
2. SE means Standard Error, and refers to the degree of uncertainty in a value.
3. Residual represents the difference between the expected value of an item, calculated according to the Rash measurement model and the actual value.
4. DegFree stands for degrees of freedom, and refers to the number of scores in a distribution that are free to change without changing the mean distribution.
5. ChSq stands for Chi-square
6. Prob relates to the probability based on the Chi-square and refers to the levels of certainty to which an item fits the measurement model.

For Figure Ground Letters in Words, all the items fit the measurement model with probabilities greater than p=0.06 (see Table 8.3), but a few of the residuals are a little outside what might be considered good limits.

For Figure Ground Numbers in Calculations, all the items fit the measurement model with probabilities greater than p=0.08 (see Table 8.4) and residuals are very satisfactory.

Table 8.3:

Individual Item Fit Statistics for Figure Ground Letters in Words

Item	Location	SE	Residual	DegFree	ChiSq	DegFree	Prob
11	-1.16	0.27	-0.68	176.65	3.20	3	0.36
13	-1.13	0.27	-0.57	176.65	4.06	3	0.25
26	-1.13	0.27	-0.59	176.65	5.23	3	0.16
9	-1.07	0.27	-1.18	176.65	2.09	3	0.55
3	-0.98	0.26	-0.23	176.65	1.17	3	0.76
15	-0.83	0.25	-1.11	176.65	3.78	3	0.29
23	-0.81	0.25	-1.96	176.65	3.00	3	0.39
6	-0.78	0.25	+0.69	176.65	2.43	3	0.49
27	-0.71	0.24	+0.31	176.65	2.85	3	0.41
12	-0.68	0.24	-1.52	176.65	3.29	3	0.35
19	-0.65	0.24	-2.12	176.65	4.92	3	0.18
5	-0.61	0.24	-1.67	176.65	2.24	3	0.52
20	-0.55	0.23	-1.71	176.65	4.24	3	0.24
7	-0.53	0.23	-0.58	176.65	3.18	3	0.37
8	-0.41	0.23	-1.42	176.65	3.13	3	0.37
25	-0.38	0.23	-0.88	176.65	2.65	3	0.45
10	-0.22	0.22	-0.69	176.65	6.37	3	0.09
16	-0.02	0.21	-0.49	176.65	6.68	3	0.08
18	+0.17	0.20	-1.56	176.65	5.05	3	0.17
29	+0.30	0.20	-0.57	176.65	0.82	3	0.84
17	+0.36	0.20	0.55	176.65	3.00	3	0.39
14	+0.43	0.20	-0.59	176.65	0.57	3	0.90
30	+0.68	0.19	-0.22	176.65	4.64	3	0.20
22	+0.69	0.19	+1.98	176.65	7.48	3	0.06
24	+0.70	0.19	-0.33	176.65	2.33	3	0.51
31	+0.84	0.19	+0.75	176.65	4.87	3	0.18
41	+0.86	0.19	-1.03	176.65	2.19	3	0.53
33	+0.88	0.19	-2.31	176.65	3.25	3	0.36
28	+0.96	0.18	+0.65	176.65	0.72	3	0.87
36	+0.99	0.18	-2.40	176.65	6.82	3	0.08
40	+1.08	0.18	+0.09	176.65	0.86	3	0.84
35	+1.17	0.18	-0.53	176.65	3.65	3	0.30
38	+1.19	0.18	-2.13	176.65	3.34	3	0.34
34	+1.36	0.18	+1.97	176.65	3.52	3	0.32

Table 8.4:

Individual Item Fit Statistics for Figure Ground Numbers in Calculations

Item	Location	SE	Residual	DegFree	ChiSq	DegFree	Prob
13	-0.94	0.20	-0.46	159.60	2.45	4	0.65
12	-0.88	0.20	-0.44	159.60	3.26	4	0.52
7	-0.64	0.20	+0.61	159.60	2.00	4	0.74
14	-0.57	0.19	-1.19	159.60	4.76	4	0.31
8	-0.32	0.19	+0.73	159.60	2.19	4	0.70
11	-0.17	0.19	-0.27	159.60	1.93	4	0.75
10	-0.05	0.19	+1.22	159.60	2.22	4	0.70
9	+0.03	0.18	+1.12	159.60	4.67	4	0.32
20	+0.22	0.18	-1.33	159.60	3.99	4	0.41
21	+0.22	0.18	-1.52	159.60	5.38	4	0.25
16	+0.38	0.18	-0.29	159.60	4.55	4	0.34
15	+0.40	0.18	+0.79	159.60	3.36	4	0.50
25	+0.43	0.18	-1.52	159.60	8.21	4	0.08
27	+0.81	0.18	-0.79	159.60	2.90	4	0.58
24	+1.07	0.18	-1.97	159.60	7.00	4	0.14

Notes on Table 8.4:

1. Location refers to the difficulty of the item on the linear scale.
2. SE means Standard Error, and refers to the degree of uncertainty in a value.
3. Residual represents the difference between the expected value of an item, calculated according to the Rash measurement model and the actual value.
4. DegFree stands for degrees of freedom, and refers to the number of scores in a distribution that are free to change without changing the mean distribution.
5. ChSq stands for Chi-square
6. Prob relates to the probability based on the Chi-square and refers to the levels of certainty to which an item fits the measurement model.

Targeting

The RUMM2020 program produces a student-measure item-difficulty or targeting graph on which the student measures are placed on the same scale as the item difficulties in standard units called logits. For Form Constancy of Letters and Numbers (see Figure 8.1), this targeting graph shows that the student measures cover a range of about -3.5 to +3.5 logits and the item difficulties cover a range of about -1.0 to +1.4 logits. From the graph it can be seen that many students (about 245) were able to answer the items correctly, while about 30 students were unable to answer any of these items correctly. This indicates that the targeting of the items needs to be improved in any future use of the scale by adding in some easier and more difficult items to ‘cover’ the students with the lowest and highest measures.

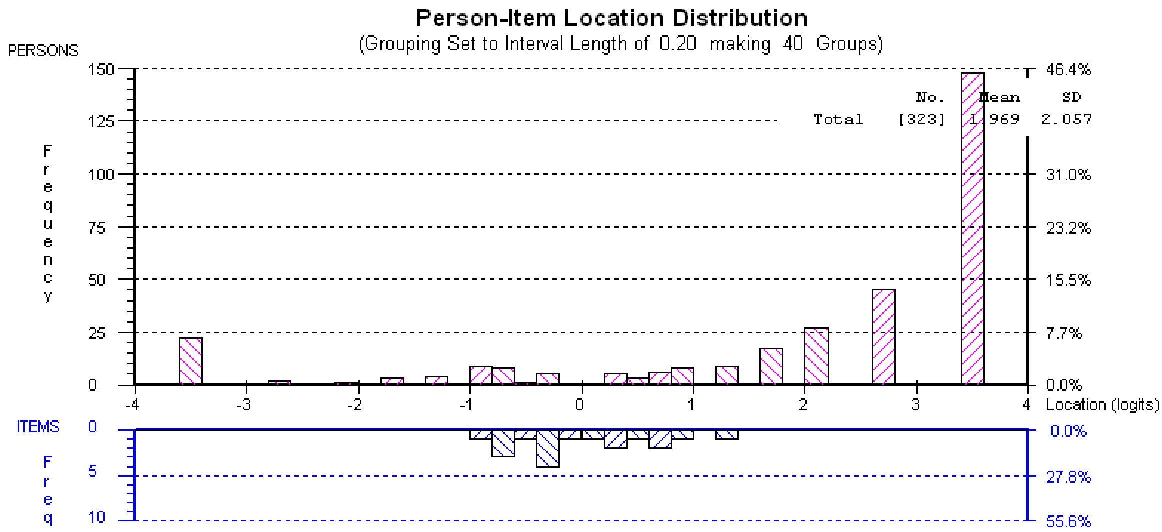


Figure 8.1 Targeting Graph for Form Constancy of Letters and Numbers
Note: Student measures are on the upper side in logits. Item difficulties are on the lower side of the same scale in logits. Many students (about 245) answered the items correctly.

For Figure Ground Letters in Words (see Figure 8.2), the targeting graph shows that the student measures cover a range of about -4.4 to +4.3 logits and the item difficulties cover a range of about -1.2 to +1.4 logits. From the graph it can be seen that many students (about 205) were able to answer the items correctly, while about 45 students were unable to answer these items. This indicates that the targeting of the items needs to be improved in any future use of the scale by adding in some easier and more difficult items to 'cover' the students with the lower and higher measures.

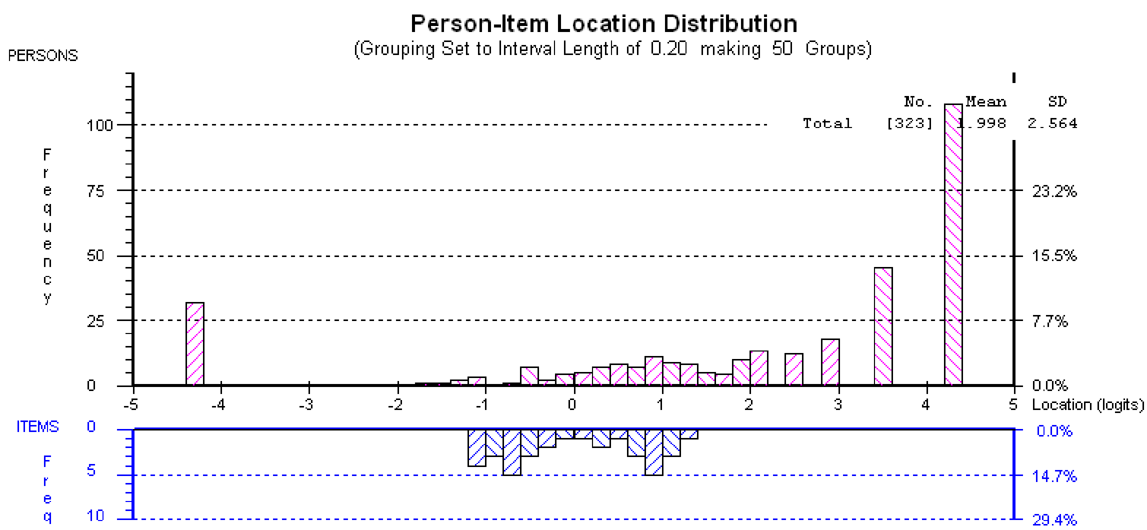


Figure 8.2: Targeting Graph for Figure Ground Letters in Words
Note: Student measures are on the upper side in logits. Item difficulties are on the lower side of the same scale in logits. Many students (about 175) answered the items correctly.

For Figure Ground Numbers in Calculations (see Figure 8.3), the targeting graph shows that the student measures cover a range of about -3.4 to +3.3 logits and the item difficulties cover a range of about -1.0 to +1.2 logits. From the graph it can be seen that many students (about 195) were able to answer the items correctly, while about 42 were unable to answer any items correctly, thus the targeting of the items needs to be improved in any future use of the scale by adding in some easier and more difficult items to 'cover' the students with the lower and higher measures.

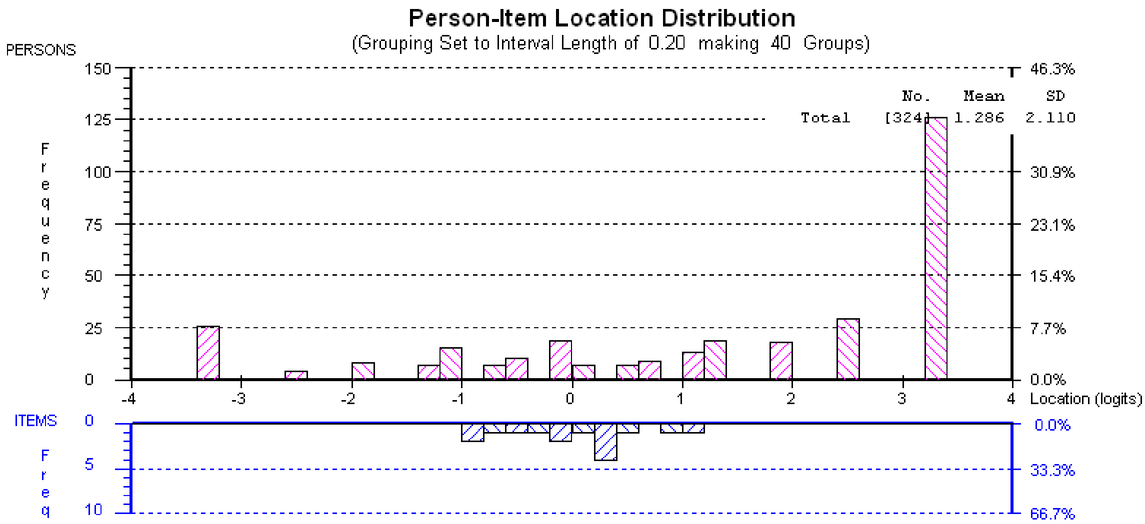


Figure 8.3: Targeting for Figure Ground Numbers in Calculations
Note: Student measures are on the upper side in logits. Item difficulties are on the lower side of the same scale in logits. Many students (about 215) answered the items correctly.

Discrimination

Item Characteristic Curves examine the relationship between the expected response and the mean group student measures. These curves display how well the item discriminates between groups of persons. An example of one item characteristic curve for each of the three constructs will be presented. Figure 8.4 shows the Item Characteristic Curve for Item 1 Form Constancy of Letters and Numbers. This curve shows that the item discriminates well for students with different measures. The Item Characteristic Curves for all the other items were checked and found to be satisfactory (but are not reported here to avoid unnecessary repetition).

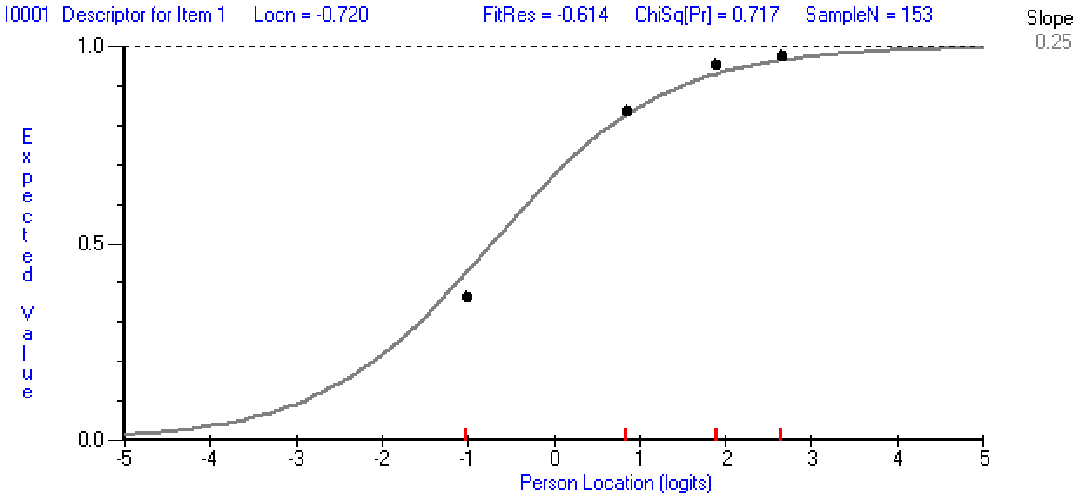


Figure 8.4: Item Characteristic Curve: Item 1 – Form Constancy of Letters and Numbers

Figures 8.5 and 8.6 respectively show the Item Characteristic Curves for Item 16 of Figure Ground of Letters in Words and Item 4 of Figure Ground Numbers in Calculations. Both these items discriminate well for students with different measures. The Item Characteristic Curves for all the other items in both measures were checked and found to be satisfactory (but are not reported here to avoid unnecessary repetition).

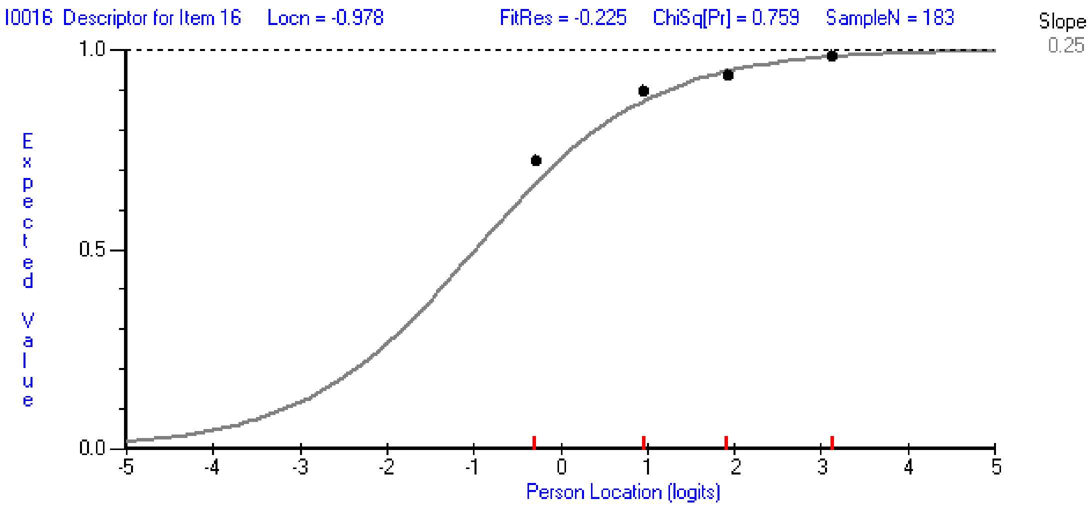


Figure 8.5: Item Characteristic Curve: Item 16 –Figure Ground of Letters in Words

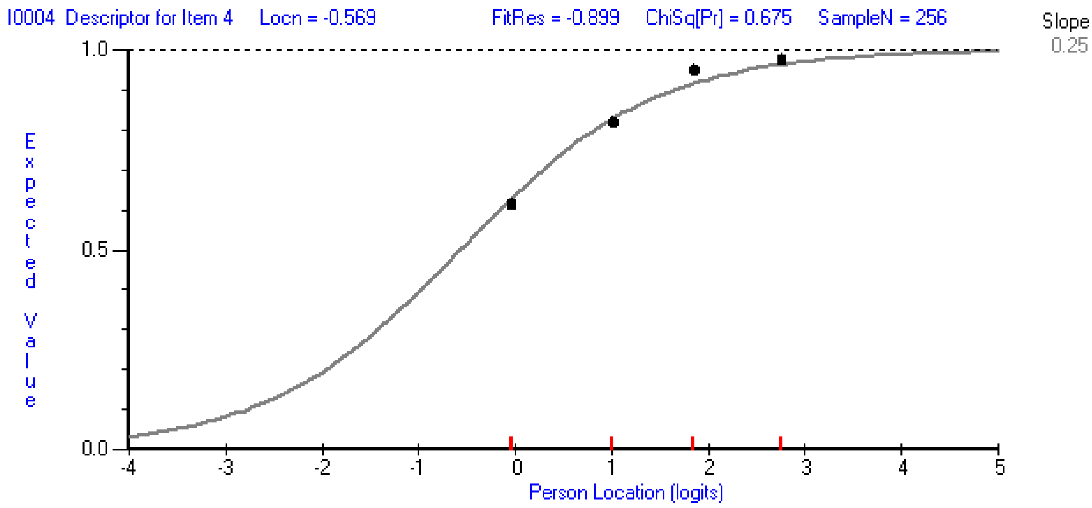


Figure 8.6: Item Characteristic Curve: Item 4 – Figure Ground Numbers in Calculations

Consistency of Use of Scoring Categories

The RUMM2020 program produces graphs of the scoring categories for each item. The Scoring Category Curves show the relationship between the probability of scoring in each category (zero for incorrect answer and one for correct answer) on each item. Figure 8.7 is the Scoring Category Curve for item 1 of Form Constancy of Letters and Numbers. This figure shows that the scoring was done logically and consistently. When students have low measures on item 1, then they have a high probability of obtaining a zero score (answer incorrect) and, when they have a high measure, they have a high probability of scoring 1 (answer correct). The Scoring Category Curves for all the other items were checked and they were satisfactory too. The Scoring Category Curves for all the items of the other two variables, Figure Ground Letters in Words and Figure Ground Numbers in Calculations, were checked and they were also found to be satisfactory, but they are not presented here to avoid repetition.

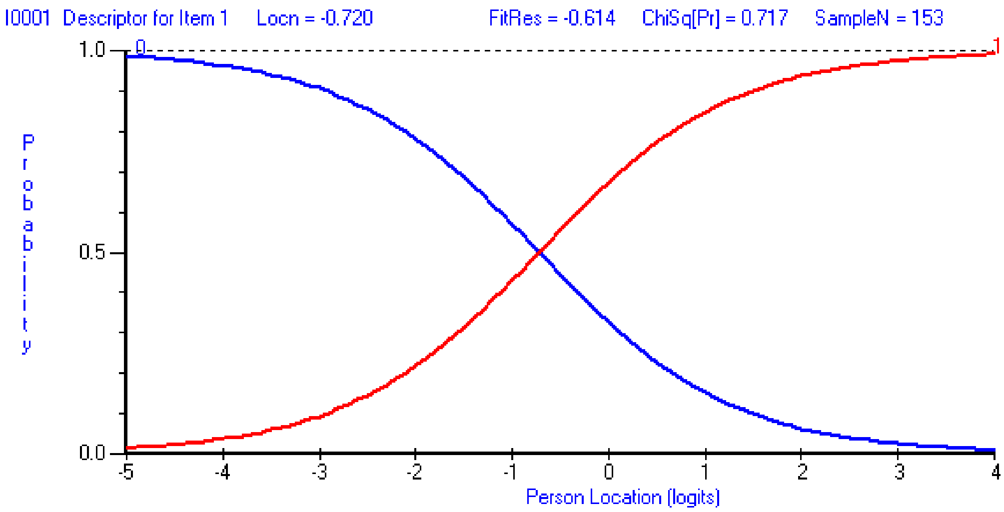


Figure 8.7: Scoring Category Curve: Item1 – Form Constancy of Letters and Numbers

Characteristics of the Sample (FCLN, FGLIW, FGNIC)

The measures for Form Constancy of Letters and Numbers (FCLN) were displayed in a graphical format separated by gender (Figure 8.8), type of school (Figure 8.9), age (Figure 8.10), grade (Figure 8.11) and whether intervention had been received (Figure 8.12). The mean differences were then tested for statistical significance using t-tests. Females have a higher mean measure than males for Form Constancy of Letters and Numbers but this is not statistically, significantly different (t=0.76, df=321, p=0.25). Public school students have a higher mean measure than private school students for Form Constancy of Letters and Numbers but this is not statistically, significantly different (t=0.93, df=321, p=0.18). As would be expected, the mean measures generally increased by age (but not consistently) from four years of age (lowest) to nine years of age (highest) and this was statistically, significantly different (t=7.9, df=65, p=0.000). Again, as expected, the mean measures generally increased by grade from Pre-primary (lowest) to Year 3 (highest) and this was statistically, significantly different (t=12.0, df=126, p=0.000). While the mean measures for no intervention were higher than for intervention, this was not statistically, significantly different (t=0.88, df=321, p=0.20).

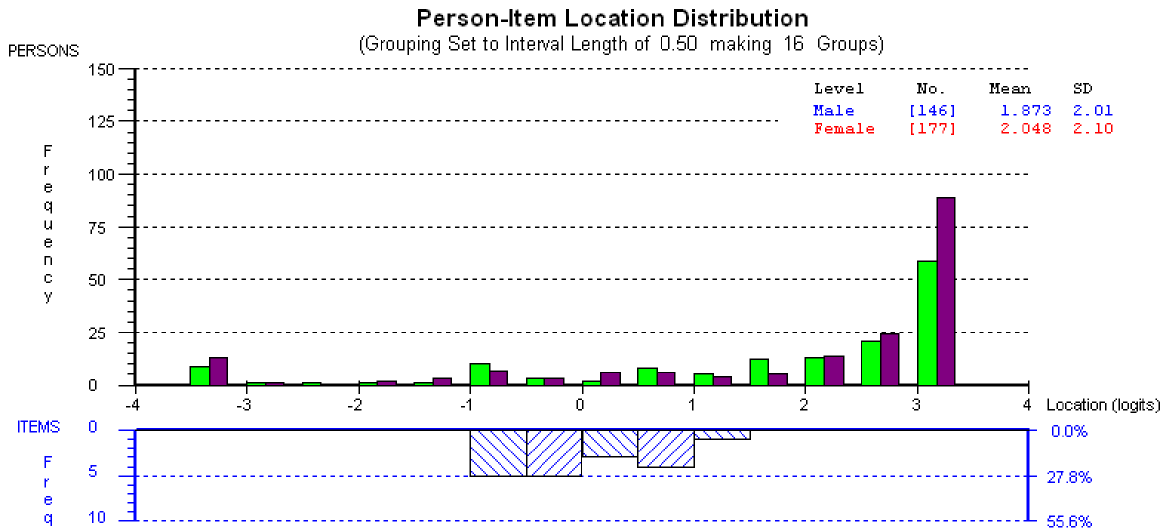


Figure 8.8: Target Graph by Gender for Form Constancy of Letters and Numbers
Note: There is a colour error in the RUMM program. Purple represents the females (not red) and green represents the males (not blue).

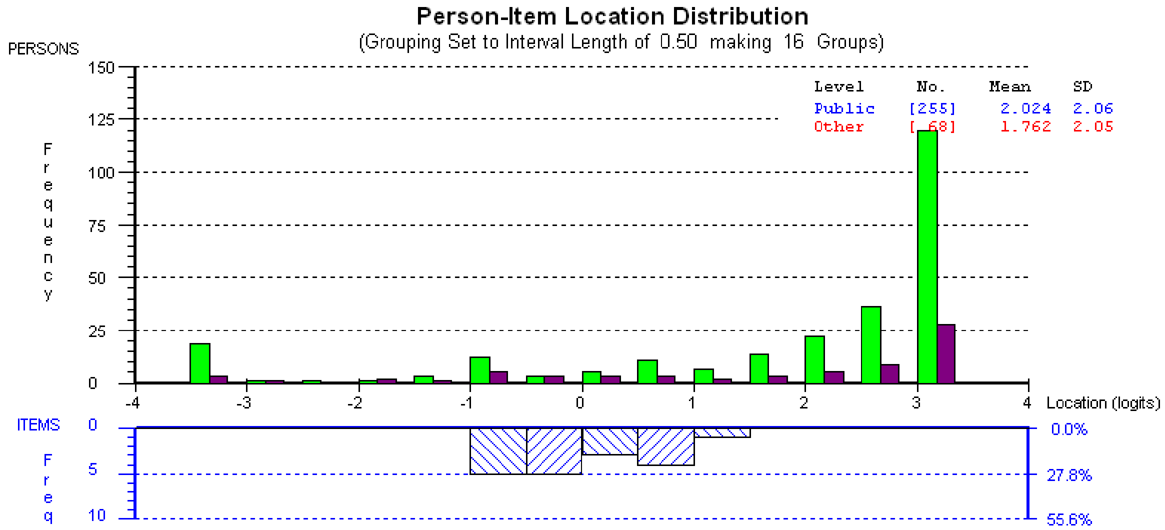


Figure 8.9: Target Graph by Type of School for Form Constancy of Letters and Numbers
Note: There is a colour error in the RUMM program. Purple represents other schools (not red) and green represents the public schools (not blue).

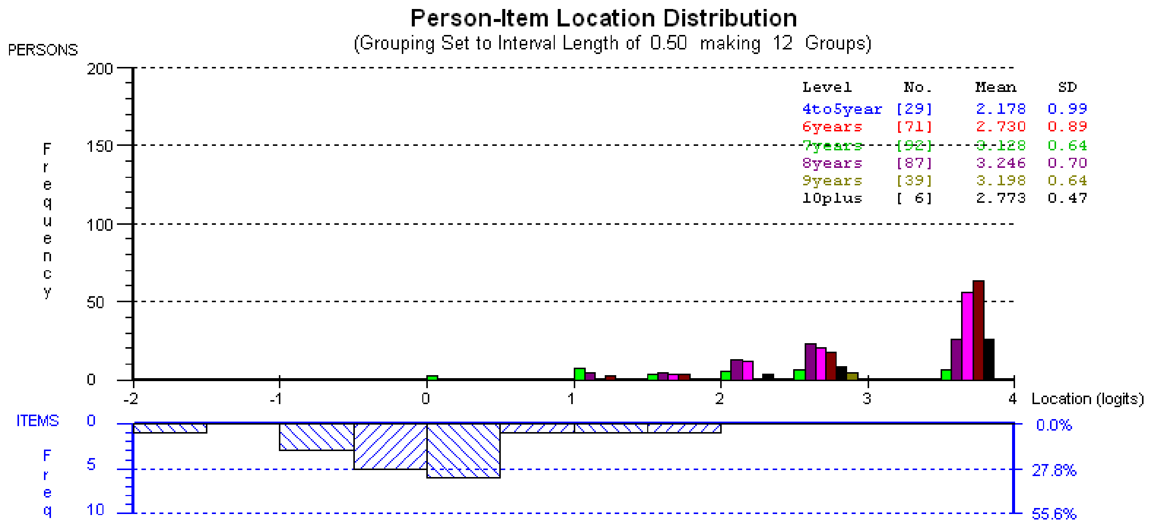


Figure 8.10: Target Graph by Age for Form Constancy of Letters and Numbers

Note: There is a colour error in the RUMM program. Four and five year olds are represented by green (not blue), six year olds are represented by Purple (not red), seven year olds are represented by pink (not green), eight year olds are represented by maroon (not purple), nine year olds are represented by black (not brown-green) and ten years and above are represented by brown-green (not black).

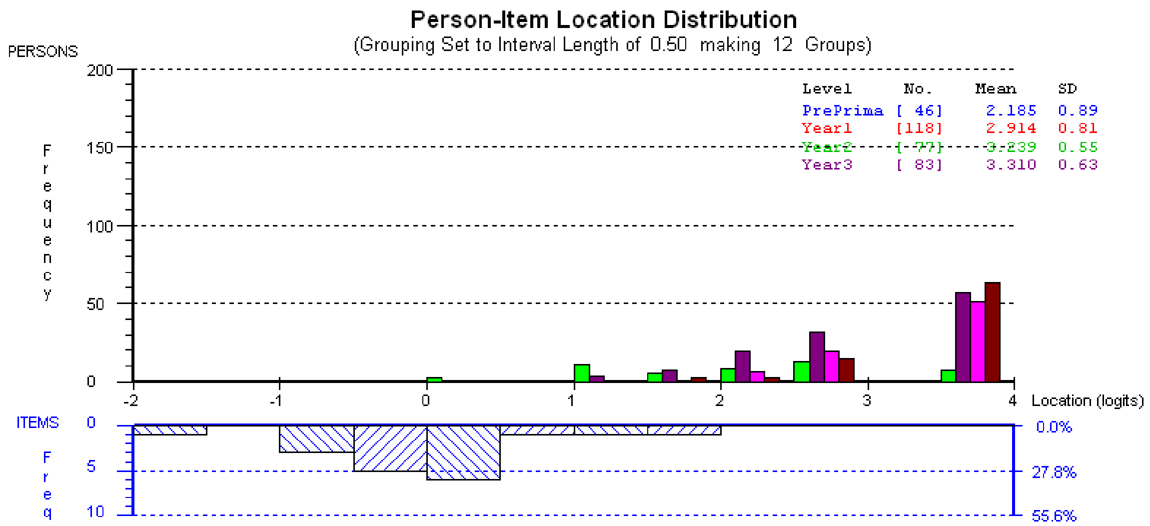


Figure 8.11: Target Graph by School Year for Form Constancy of Letters and Numbers

Note: There is a colour error in the RUMM program. Pre-primary is represented by green (not blue), Year 1 is represented by purple (not red), Year 2 is represented by pink (not green), and Year 3 is represented by maroon (not purple).

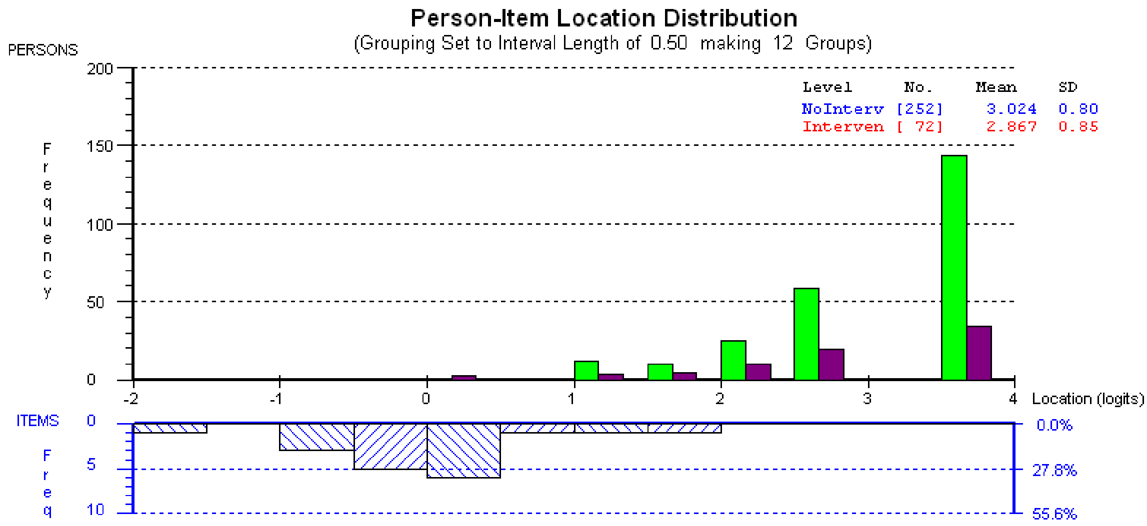


Figure 8.12: Target Graph by Intervention for Visual Form Constancy of Letters and Numbers

Note: There is a colour error in the RUMM program. Green represents no intervention and purple intervention.

The graphical data for Figure Ground Letters in Words were checked in the RUMM computer program but is not produced here to avoid repetition but the graphs are similar to those produced for Form Constancy of Letters and Numbers. Females had a higher mean measure than males for Figure Ground Letters in Words but this is not statistically, significantly different (t=1.90, df=321, p=0.025). Public school students had a higher mean measure than private school students for Figure Ground Letters in Words and this is statistically, significantly different (t=3.6, df=321, p=0.000) in favour of the public schools. As would be expected, the mean measures generally increased by age from four years old (lowest) to ten years old or older (highest) and this was statistically, significantly different (t=8.10, df=66, p=0.000). Again, as expected, the mean measures generally increased by grade from Pre-primary (lowest) to Year 3 (highest) and this was statistically, significantly different (t=21.2, df=127, p=0.000). While the mean measure for no intervention was higher than for intervention, this was not statistically, significantly different (t=0.71, df=321, p=0.25).

The graphical data for Figure Ground Numbers in Calculations was also checked in the RUMM computer program but is not produced here to avoid too much repetition; however the graphs are similar to those produced for Form Constancy of Letters and Numbers. Females have a higher mean measure than males for Figure Ground Numbers in Calculations and this is statistically, significantly different (t=2.98, df=322, p=0.000). Public school students had a higher mean measure than private school students for Figure Ground Numbers in Calculations and this is statistically, significantly different (t=2.44, df=322, p=0.002) in favour of the public schools. As would be expected, the mean measures generally increased by age from four years old (lowest) to ten years old or older (highest) and this was statistically, significantly different (t=10.2, df=66, p=0.000). Again, as expected, the mean measures generally increased by grade from Pre-primary (lowest) to Year 3 (highest) and this was statistically, significantly different (t=22.5, df=127, p=0.000). While the mean measure for no intervention was higher than for intervention, this was not statistically significantly different (t=1.64, df=322, p=0.05).

Final Items for the Form Constancy and Figure Ground Scales

The final 18 items and their difficulties are presented, in order from easiest to hardest, in Table 8.5 for Form Constancy of Letters and Numbers. The students found it easy to identify the reversed item for the letter 'a' and for numbers. They found it moderately easy to identify the reversed letters that are not often reversed in the font used in this scale (e.g. e, b, c), moderately difficult to identify letters that could be reversed or letters that had a body and a tail (e.g. s, q, y) and most difficult to identify the reversed letters that are commonly written in a reversed orientation by young students (e.g. j, g, d).

In the Figure Ground Letters in Words (see Table 8.6 for the 34 item difficulties ordered from easy to hard), students found it easy to identify words as correct when they did not contain a reversed letter, such as: the, ran, that, know, and moderately easy to identify words as correct or incorrect when they had a mixture of long and short letters, for example black, how, little. Longer words containing a reversed letter were moderately difficult for students to identify as correct or incorrect, for example because, thank, round; while the most difficult words to identify as correct or incorrect were those with reversed orientation of g and u (e.g. upon, bring, right).

In the Figure Ground Numbers in Calculations (see Table 8.7 for the 15 item difficulties ordered from easy to hard), the students found it very easy to identify the reversed numbers in a simple plus or subtract calculation where the numbers were under

20 (e.g.ƍ – 5 = 1, 5+ϛ=7) and found it moderately easy to identify the reversed number in addition and subtraction calculations where the numbers were in the teens or above 20 such as 4 + 2Ɛ = 27. Moderate difficulty was experienced in identifying reversed numbers in larger numbers or when the division sign was used for example: 21 ÷ 3 = Ⲧ, 72 – 8 = 64 and the students found it most difficult to identify the reversed number in vertically arranged calculations such as 35 − Ⲧ / 28.

Table 8.5

Difficulties for 18 Final Items in Form Constancy of Letters and Numbers

Item No	Item	Difficulty	SE
18 (easiest)		-0.93	0.26
1		-0.72	0.25
23		-0.70	0.25
21		-0.63	0.24
19		-0.50	0.24
20		-0.40	0.23
5		-0.33	0.23
2		-0.33	0.23
3		-0.26	0.23
8		-0.12	0.23
14		+0.10	0.22
13		+0.28	0.21
16		+0.29	0.21
11		+0.51	0.21
17		+0.70	0.20
9		+0.71	0.20
7		+0.93	0.20
4 (hardest)		+1.39	0.19

Note: Items are ordered from easiest (item 18, -0.93 logits) to hardest (item 4, +1.39 logits)
SE means Standard Error

Table 8.6:

Difficulties for 34 Final Items in Figure Ground Letters in Words Scale

Item No	Item Word	Difficulty	SE	Item No	Item Word	Difficulty	SE
11 (easiest)	ran	-1.16	0.27	16	yes	-0.02	0.21
13	that	-1.13	0.27	18	ask	0.17	0.20
26	know	-1.13	0.27	29	open	0.30	0.20
9	new	-1.07	0.27	17	after	0.36	0.20
3	am	-0.98	0.26	14	they	0.43	0.20
15	white	-0.83	0.25	30	because	0.68	0.19
23	stop	-0.81	0.25	22	thank	0.69	0.19
6	did	-0.80	0.25	24	round	0.70	0.19
27	when	-0.71	0.24	31	cold	0.84	0.19
12	saw	-0.68	0.24	41	today	0.86	0.19
19	could	-0.65	0.24	33	green	0.88	0.19
5	black	-0.61	0.24	28	walk	0.96	0.18
20	how	-0.55	0.23	36	your	0.99	0.18
7	four	-0.53	0.23	40	pick	1.08	0.18
8	little	-0.41	0.23	35	upon	1.17	0.18
25	give	-0.38	0.23	38	bring	1.19	0.18
10	please	-0.22	0.22	34(hardest)	right	1.36	0.18

Note: Items are ordered from easiest (item 11, -1.16 logits) to hardest (item 34, +1.36 logits)
SE means Standard Error

Table 8.7:

Difficulties for 15 Final Items in Figure Ground Numbers in Calculations Scale

Item No	Item Calculation	Difficulty	SE	Item No	Item Letter	Difficulty	SE
13 (easy)	∂ – 5 = 1	-0.94	0.20	20	21 ÷ 3 = ⟍	+0.22	0.18
12	12 – ᔭ = 8	-0.88	0.20	21	6Ƨ + 12 = 77	+0.22	0.18
7	5 + ᘔ = 7	-0.64	0.20	16	72 – 8 = 6ᔭ	+0.38	0.18
14	60 + 5 = ∂5	-0.57	0.20	15	Ɛ1 + 4 = 35	+0.40	0.18
8	ρ + 4 = 13	-0.32	0.20	25	3 / ρ = 3	+0.43	0.18
11	⟍ + 9 = 16	-0.17	0.20	27	1Ƨ × 6 = 90	+0.81	0.18
10	4 + 2Ɛ = 27	-0.05	0.20	24(hardest)	35 – ⟍ = 28	+1.07	0.18
9	9 – Ƨ = 4	0.03	0.18				

Note: Items are ordered from easiest (item 13, -0.94 logits) to hardest (item 24, +1.07 logits)
SE means Standard Error

Comments on the Non-Fitting Items Deleted from the Three scales

Six items were deleted from the Form Constancy of Letters and Numbers Scale due to poor fit to the Rasch measurement model. Usually the main reason for non-fit is poor agreement in regard to the item difficulty. For example, half of the medium ability students may say an item is easy and half say that it is hard, thus it does not fit the measurement model and is deleted. The six items deleted in Form Constancy of Letters and Numbers Scale were: f, k, p, t, 6, and 9. One reason for the students' disagreement on these letters may be due to the font used in this assessment, however it was noted that many students chose the upper case letter or the same letter as the reversed letter in a number of these situations as well as the same number or the number that had been made smaller, indicating that there are complex processes at work in these perceptual tasks. It is also of particular interest that most of the letters and numbers deleted due to disagreement were the letters and numbers that students often tend to reverse.

In Figure Ground Letters in Words, seven of the original 41 words were deleted due to non-fit to the Rasch measurement model. The deleted letters were the words one (with reversed e), come, ate (with reversed t), think, fast (with reversed t), together (with reversed h) and never (with reversed n). It is noticeable that five of the words with poor fit had reversed letters; however there is no noticeable pattern of the similarity of letter or position of the reversed letter in the words. The font used in the assessment may have been a contributing factor to the students' interpretation of these words; however this does not present as an obvious influencing factor, as language, reading ability and spelling concepts may also be influencing factors in this complex perceptual process..

Thirteen of the original calculations were deleted in Figure Ground Numbers in Calculations due to non-fit to the Rasch measurement model. The calculations excluded from the analysis were three items where the student identified the number of pictures, and three calculations with numbers all under five (six easiest calculations), three horizontal divide or multiplication calculations as well as four horizontally positioned calculations, which included reversed numbers in any position of the calculation. The alignment of the calculations, the operation sign or the development of number concept may have had an influencing factor on the students' responses.

Inferences from the Measures of the Three Linear Rasch Scales

Linear scales were created that show good fit to the measurement model for the Form Constancy of Letters and Numbers, Figure Ground Letters in Words and Figure Ground Numbers in Calculations. Valid inferences can now be made about the student measures for form constancy and figure ground perception from these three linear scales. The bottom 49 student measures for Form Constancy of Letters and Numbers have been taken because these students all scored 6/18 or less, meaning that they were the students who were unable to identify the letters (other than a) and were only able to achieve some of the items that contained numbers. Twenty-two students had a score of zero with a location of -3.45, a standard error of 1.24. These student measures are presented in Table 6.8.

The students who scored zero in Form Constancy of Letters and Numbers were unable to answer any of the items correctly, suggesting that they either misunderstood the instruction or are unable to identify when numbers or letters are reversed when the letters and numbers are presented in a variety of fonts. Students who scored 6 had difficulty identifying the reversed letters, but were more capable when identifying reversed numbers in different fonts. Students scoring poorly in Form Constancy of Letters and Numbers have difficulty identifying when letters and numbers of differing fonts are reversed and may need extra assistance to improve this skill.

Table 8.8:

Lowest 49 Student Measures for Form Constancy of Letters and Numbers

ID	Raw score	Location	SE	Residual	ID	Raw score	Location	SE	Residual
151	0	-3.45	1.24	-	80	3	-1.62	0.62	-0.59
199	0	-3.45	1.24	-	5	3	-1.62	0.62	-0.43
167	0	-3.45	1.24	-	119	3	-1.62	0.62	0.12
166	0	-3.45	1.24	-	18	4	-1.28	0.57	0.30
165	0	-3.45	1.24	-	84	4	-1.28	0.57	1.06
164	0	-3.45	1.24	-	111	4	-1.28	0.57	-0.95
324	0	-3.45	1.24	-	223	4	-1.28	0.57	-0.11
162	0	-3.45	1.24	-	76	5	-0.99	0.54	-1.09
203	0	-3.45	1.24	-	78	5	-0.99	0.54	-1.09
153	0	-3.45	1.24	-	23	5	-0.99	0.54	-0.62
163	0	-3.45	1.24	-	268	5	-0.99	0.54	-1.09
150	0	-3.45	1.24	-	49	5	-0.99	0.54	-1.09
27	0	-3.45	1.24	-	66	5	-0.99	0.54	0.56
21	0	-3.45	1.24	-	46	5	-0.99	0.54	-1.09
19	0	-3.45	1.24	-	16	5	-0.99	0.54	-0.99
4	0	-3.45	1.24	-	224	5	-0.99	0.54	-0.85
3	0	-3.45	1.24	-	319	6	-0.73	0.52	-1.28
108	0	-3.45	1.24	-	234	6	-0.73	0.52	-0.60
37	0	-3.45	1.24	-	65	6	-0.73	0.52	1.18
156	0	-3.45	1.24	-	205	6	-0.73	0.52	1.33
323	0	-3.45	1.24	-	83	6	0.73	0.52	0.35
161	0	-3.45	1.24	-	22	6	-0.73	0.52	-0.95
200	1	-2.62	0.89	-0.93	297	6	-0.73	0.52	0.51
64	1	-2.62	0.89	0.16	317	6	-0.73	0.52	0.85
110	2	-2.04	0.71	-0.58					

The bottom 53 student measures for Figure Ground Letters in Words have been taken because these students scored less than 17 out of 34, meaning that they were unable to identify more than half of the items as having or not having a reversed letter within the word. These student measures are presented in Table 8.9. Students, who scored 7, were only able to correctly identify items where no reversed letters occurred in the word. The students scoring 17 correct answers were able to identify words containing no reversals and the easiest four words containing a reversed letter. The four easiest items containing a reversed letter consisted of three words where a letter with a body as well as a head (long letter) and one word where a short letter with only a body was reversed. These student measures identify students who may require assistance to improve their skill in identifying when a letter is reversed within a word. They may also be the students who reverse their letters in reading, spelling and or writing.

Table 8.9:

Lowest 53 Student Measures Figure Ground Letters in Words

ID	Raw score	Location	SE	Residual	ID	Raw score	Location	SE	Residual
324	0	-4.20	1.22	-	24	0	-4.20	1.22	-
65	0	-4.20	1.22	-	25	0	-4.20	1.22	-
66	0	-4.20	1.22	-	26	0	-4.20	1.22	-
80	0	-4.20	1.22	-	27	0	-4.20	1.22	-
82	0	-4.20	1.22	-	2	0	-4.20	.122	-
83	0	-4.20	1.22	-	84	6	-1.69	0.46	0.38
150	0	-4.20	1.22	-	67	7	-1.49	0.44	0.04
64	0	-4.20	1.22	-	202	8	-1.31	0.42	-1.60
156	0	-4.20	1.22	-	237	8	-1.31	0.42	1.29
79	0	-4.20	1.22	-	162	9	-1.15	0.41	-1.10
164	0	-4.20	1.22	-	3	9	-1.15	0.41	-1.01
166	0	-4.20	1.22	-	57	9	-1.15	0.41	1.99
167	0	-4.20	1.22	-	20	12	-0.69	0.38	-0.89
276	0	-4.20	1.22	-	4	13	-0.55	0.38	-1.45
199	0	-4.20	1.22	-	8	13	-0.55	0.38	-1.45
203	0	-4.20	1.22	-	209	13	-0.55	0.38	0.13
205	0	-4.20	1.22	-	110	14	-0.41	0.37	1.66
151	0	-4.20	1.22	-	78	14	-0.41	0.37	-2.72*
23	0	-4.20	1.22	-	74	14	-0.41	0.37	0.24
18	0	-4.20	1.22	-	62	14	-0.41	0.37	-2.16
81	0	-4.20	1.22	-	206	15	-0.27	0.37	0.19
12	0	-4.20	1.22	-	208	15	-0.27	0.37	-2.54*
323	0	-4.20	1.22	-	114	16	-0.14	0.37	-3.30*
5	0	-4.20	1.22	-	111	16	-0.14	0.37	-1.20
16	0	-4.20	1.22	-	317	17	-0.01	0.37	-1.05
22	0	-4.20	1.22	-	200	17	-0.01	0.37	4.15*
37	0	-4.20	1.22	-					

Notes on Table 8.9: *: Fit residual value exceeds limit set for test of fit

The bottom 45 student measures for Figure Ground Numbers in Calculations have been chosen because these students scored three or less out of fifteen correct, meaning that they were only able to identify reversed numbers in calculations containing numbers smaller than 12 and the reversed number was standing alone in the equation and was not part of a number greater than nine. These student measures are presented in Table 8.10. Students who scored zero out of 15 were unable to identify any reversed numbers. Students scoring three were only able to identify reversed numbers in simple calculations where the reversed number stood alone.

Table 8.10:

Lowest 45 Student Measures Figure Ground Numbers in Calculations

ID	Raw score	Location	SE	Residual	ID	Raw score	Location	SE	Residual
2	0	-3.25	1.27	-	18	0	-3.25	1.27	-
201	0	-3.25	1.27	-	323	0	-3.25	1.27	-
167	0	-3.25	1.27	-	161	0	-3.25	1.27	-
166	0	-3.25	1.27	-	27	1	-2.41	0.90	-0.95
324	0	-3.25	1.27	-	24	1	-2.41	0.90	-0.90
162	0	-3.25	1.27	-	20	1	-2.41	0.90	-0.90
156	0	-3.25	1.27	-	208	1	-2.41	0.90	-0.41
153	0	-3.25	1.27	-	223	2	-1.81	0.73	-0.68
151	0	-3.25	1.27	-	111	2	-1.81	0.73	+0.10
139	0	-3.25	1.27	-	5	2	-1.81	0.73	-0.23
203	0	-3.25	1.27	-	87	2	-1.81	0.73	-0.07
16	0	-3.25	1.27	-	67	2	-1.81	0.73	-0.67
163	0	-3.25	1.27	-	200	2	-1.81	0.73	-0.19
83	0	-3.25	1.27	-	206	2	-1.81	0.73	-0.23
82	0	-3.25	1.27	-	205	2	-1.81	0.73	-0.31
81	0	-3.25	1.27	-	165	3	-1.37	0.64	-0.50
80	0	-3.25	1.27	-	23	3	-1.37	0.64	-0.38
79	0	-3.25	1.27	-	57	3	-1.37	0.64	-0.94
66	0	-3.25	1.27	-	150	3	-1.37	0.64	-1.16
65	0	-3.25	1.27	-	202	3	-1.37	0.64	+0.09
64	0	-3.25	1.27	-	26	3	-1.37	0.64	-0.82
42	0	-3.25	1.27	-	307	3	-1.37	0.64	+1.10
37	0	-3.25	1.27	-					

Summary of Findings

Linear scales were created for Form Constancy of Letters and Numbers, Figure Ground Letters in Words and Figure Ground Numbers in Calculations using the

RUMM2020 Program (Andrich et al., 2005). The reliability of the three scales was shown by:

1. Acceptable global item fit as well as person item fit to the measurement model;
2. Good Person Separation Indices indicating that the person measures were reasonably well, or acceptably well, separated in relation to the errors;
3. Acceptable item-trait interaction chi-squares indicating the measurement of a uni-dimensional trait;
4. Acceptable targeting of items against the person measures, but indicates the need for some easy and more difficult items in the scales for future use.

Valid inferences may be drawn from the scales as the scale data were shown to be reliable. Inferences are that it is easiest for students to identify reversed numbers in a variety of fonts rather than the reversed letters and that the most difficult letters for students to identify as reversed when presented among a variety of fonts were long letters as in z, j, g, and d. For Form Constancy of Letters and Numbers, girls scored more highly than boys, but this was not statistically significant. There was no statistical significant difference between private and public schools, although public schools scored a higher mean average. Furthermore, there was as expected, a statistically significant difference in the performance of students as their age and grade increased, with younger students in lower grades scoring significantly lower than the older students in the higher grades. Students with the lowest scores were those who had most difficulty identifying reversed letters and numbers among a selection of letters and numbers presented in a variety of fonts.

For Figure Ground Letters in Words the girls scored a higher mean average than boys, but this was not statistically significant. Public schools scored a statistically significant higher mean value than private schools. The younger students in the lower grades scored a lower mean value than the older students in the higher grades and this was statistically significant as would be expected. Students with the lowest scores had difficulty identifying words that contained a reversed letter as opposed to words that did not have a reversed letter embedded in the word.

In Figure Ground Numbers in Calculations, the girls scored a statistically significantly higher mean average than the boys. Students in public schools had a statistically significantly higher mean average than private schools for this scale. Mean values increased with age from the youngest students (four years old) to the oldest students (10 plus years old) with a statistically significant difference. The mean values increased by grade from Pre-primary to Grade 3 with a statistically significant difference. Students with the lowest measures had difficulty identifying reversed numbers within the context of a calculation.

The next chapter focuses on the lowest student measures in the eight scales. Inferences that can be validly made from these measures will also be explained by contrasting and comparing these measures.

CHAPTER NINE

DATA ANALYSIS (PART FOUR)

STUDENTS WITH THE LOWEST RASCH MEASURES

In the previous chapters, the RUMM computer program was used to create eight, unidimensional linear scales relating to various aspects of letter and number discriminations and reversals. Aspects of the RUMM output include tables of data where students with the lowest measures for each scale can be identified. The connections between these students (identified only by number for ethical reasons) are presented in this data analysis chapter (part four), involving their inter-connections across measures in the eight scales. Inferences drawn from the inter-connections across the eight linear Rasch scales are presented.

Lowest Student Measures

The number of students with the lowest measures included in the Visual Discrimination of Upper Case Letters was 19, in Visual Discrimination of Lower Case Letters 21 students, in Visual Discrimination of Numbers 15 students, and in Spatial Orientation of Letter and Number Pairs 24 students. In the remaining four scales, a larger number of students with low measures were taken as many students scored zero in these scales. This resulted in 35 students with low measures for Spatial Orientation of Letter and Number Sequencing, 49 students with low measures for Form Constancy of Letters and Numbers, 53 students with low measures for Figure Ground Letters in Words and 45 students with low measures for Figure Ground Numbers in Calculations. A comparison of the lowest student measures in each of these scales was made and analysed. This information is set out below.

Students with Low Measures across all Scales

Four students (27, 80, 81, and 323) scored poorly (in the lowest 15 to 30 students) on seven or eight of the scales. The cut-offs for the lowest measures were somewhat arbitrary and were made according to 'natural' breaks in the measures. This means that these students had difficulty in all areas of letter and number identification related to visual discrimination, spatial orientation, sequencing, form constancy and figure ground, as measured in the present study, including number and letter identification such as in L, D, j, z, and 9, as well as in number and letter reversals such as ᑫ, ƨ, and ∂. This observation, together with the results showing that students who were often able to discriminate letters and numbers (but not necessarily on every occasion) were also often able to identify reversals, supports the theory that students need to be able to visually discriminate individual letters and numbers before they are able to manipulate or identify reversed letters and numbers in context. Table 9.1 shows some characteristics of these four students. Two of these students were boys who were receiving intervention and/or assistance for learning difficulty and two of these students were girls in private schools who had not received any previous intervention or assistance at school. It is worth noting that these students with the lowest measures all include the younger students in the lowest grade, indicating that the scale does target students with difficulties or undeveloped skills in this area. Thus, it can be concluded that these four students have difficulty with identification of letter and number reversals and would benefit from additional assistance in this area.

Student number 323 scored 8/14 for Visual Discrimination of Numbers, the only scale where he was not among the reported students with low measures (see Table 9.2). This is one point above the cut-off used for the lowest student measures reported, however, if 31 student measures were taken (including all those who scored 8/14), then student 323 would have scored a low score in all the sub-scales. Student 27 scored 22/31 items for Visual Perception of Lower Case Letters, putting him above the cut-off for the lowest scoring students in this scale, however he scored poorly in all other scales. Students 80 and 81 scored poorly in all the scales. Learning difficulties were reported by two of the parents of these students on the demographics form; however, the effect of the difficulties with letter and number reversal recognition on schoolwork cannot be verified in this study.

Table 9.1:

Some characteristics of the four students with the lowest measures

ID	Gender	Age	Grade	School	Intervention
27	Male	5.5	0	Public	Therapy
80	Female	6.1	0	Private	No
81	Female	5.9	0	Private	No
323	Male	5.8	0	Public	Therapy + assistance

Note: Age is in years, grade 0 means pre-school

Table 9.2

Students with the lowest measures in the eight scales

ID	VDUCL	VDLCL	VDN	SOLNP	LNS	FCLN	FGLIW	FGNIC
27	√		√	√	√	√	√	√
80	√	√	√	√	√	√	√	√
81	√	√	√	√	√		√	√
323	√	√		√	√	√	√	√

Notes on Table 9.2:

1. ID means Student Identity Number
2. VDUCL means Visual Discrimination of Upper Case Letters
3. VDLCL means Visual Discrimination of Lower Case Letters
4. VDN means Visual Discrimination of Numbers
5. SOLNP means Spatial Orientation of Letter and Number Pairs
6. LNS means Letter and Number Sequencing
7. FCLN means Form Constancy of Letters and Numbers
8. FGLIW means Figure Ground Letters in Words
9. FGNIC means Figure Ground Numbers in Calculations
10. A √ means that the student was in the group with the lowest measures for that scale so, for example, student number 27 was in the group with the four lowest measures for 7 out of 8 scales

Summary for Students with Low Measures in Five or Six Scales

Sixteen students scored poorly in five or six of the scales. Some characteristics for these students are given in Table 9.3. Eight of these students were girls and eight were boys. Five of the students attended a public school. Fourteen students were in Pre-primary while one was in Grade 1 and one was in Grade 3. Five of these students were receiving some form of intervention, such as speech and language therapy, occupational therapy or special assistance at school. Twelve of these students had difficulty discriminating letters and numbers individually as well as in context, while four students (156, 167, 18 and 166) could identify the individual letters and numbers but became confused when they were combined with other letters and numbers in context such as in sequences, words and calculations (see Table 9.4). For example, Jlack, on/no and 21 ÷ 3 = ٦.

Thirteen of the fifteen students were able to discriminate individual numbers better than letters, supporting the theory that number discrimination is easier than letter discrimination because students are exposed to numbers in counting and quantity, before being exposed to letters in recognition of words in the learning context. For example, student number 164 was good at individual numbers as well as numbers in context, but had difficulty with letters in all scales. This may indicate difficulties isolated mainly to letters compared to numbers and a possible aptitude for numbers in this student.

Table 9.3:

Characteristics of students with the lowest measures across five or six scales

ID	Gender	Age	Grade	School	Intervention
5	Male	5.8	0	Public	no
18	Female	5.10	0	Public	no
37	Male	8.8	3	Private	No
64	Female	4.10	0	Private	SLT
6	Female	7.2	1	Private	No
83	Male	5.5	0	Private	No
150	Female	5.9	0	Public	No
151	Male	5.9	0	Public	No
156	Male	5.11	0	Public	No
164	Male	5.9	0	Public	Therapy
166	Female	5.8	0	Public	Therapy
167	Female	5.8	0	Public	No
200	Male	5.6	0	Public	SLT, SE
203	Male	5.7	0	Public	No
205	Female	5.5	0	Public	SLT
324	Female	5.7	0	Public	No

Notes on Table 9.3:

1. 0 under grade represents Pre-primary year
2. SLT means speech and language therapy;
3. SE means special education or teacher assistant.
4. Age is in years

Twelve of the sixteen students scored poorly in Spatial Orientation of Letter and Number Pairs, for example,Ƨ S, E Ǝ and 2 ᘔ, indicating that the directionality of letters and numbers had not yet been established. Three (167, 166, and 324) of these students scored zero for Letter and Number Sequencing: for example 378/387, Figure Ground

Letters in Words: for example they, as well as Figure Ground Numbers in Calculations: for example 5+2=7. This would be indicative of extensive difficulty in letter and number reversal recognition in context, suggesting that these students require additional assistance in all letter and number recognition skills.

Table 9.4:

Students with the lowest measures in five or six scales

ID	VDUCL	VDLCL	VDN	SOLNP	LNS	FCLN	FGLIW	FGNIC
5	√			√	√	√	√	√
18				√	√	√	√	√
37	√	√			√	√	√	√
64	√	√			√	√	√	√
66	√			√	√	√	√	√
83	√	√				√	√	√
150			√		√	√	√	√
151			√	√	√	√	√	√
156				√	√	√	√	√
164	√	√		√	√	√	√	
166				√	√	√	√	√
167				√	√	√	√	√
200		√	√	√		√	√	√
203		√		√	√	√	√	√
205		√		√		√	√	√
324	√			√	√	√	√	√

Notes on Table 9.4:

1. ID means Student Identity Number
2. VDUCL means Visual Discrimination of Upper Case Letters
3. VDLCL means Visual Discrimination of Lower Case Letters
4. VDN means Visual Discrimination of Numbers
5. SOLNP means Spatial Orientation of Letter and Number Pairs
6. LNS means Letter and Number Sequencing
7. FCLN means Form Constancy of Letters and Numbers
8. FGLIW means Figure Ground Letters in Words
9. FGNIC means Figure Ground Numbers in Calculations
10. A √ means that a student was in the group with the lowest measures in the scale so, for example, student number 5 was in the lowest group measures for six of the eight scales

Summary of Students with Low Measures in Three or Four Scales

Twenty-seven students (see Table 9.5) with low measures scored poorly in three or four of the eight sub-scales. Seventeen of these students were girls and ten were boys. Eight students were in Year 1 and 19 students were in Pre-primary, indicating that there is a trend towards the younger child in the lower grades experiencing more difficulty with letter and number reversal recognition. Two of these students' difficulties in learning had already been recognised and they were receiving additional assistance at school and/or in therapy to address their difficulties.

Fourteen out of twenty-seven students scoring poorly in three or four scales had some difficulty with individual letter and number discrimination, such as L, 9, J and 4. The remaining thirteen only displayed difficulty where letters and numbers were placed in context (see Table 9.6). For example, they could not identify the reversed letters in words (alter) and numbers or calculations (21 ÷ 3 = 7). Three students had difficulty with Figure Ground Letters in Words and Figure Ground Numbers in Calculations only, suggesting that these students' difficulties were not in the orientation of the letters and numbers but in finding them in the background of the words and calculations. These students may have difficulty reading as they will find it difficult to isolate words and lose their place when reading. For example, when reading text where the same word appears on two lines on close proximity, the student may skip to the word on the second line before completing the first line, thus when reading:

"Joe sat down on his chair and jumped up again.
Joe had sat on a pin"; the student may skip words and read "Joe sat on a pin"

Table 9.5:

Some characteristics of students with the lowest measures across three or four scales

ID	Gender	Age	Grade	School	Intervention
2	Female	5.7	0	Public	No
3	Female	5.6	0	Public	No
4	Male	6.8	1	Public	No
16	Male	5.11	0	Public	No
20	Male	5.9	0	Public	No
23	Male	6.0	0	Private	No
26	Female	5.8	0	Private	No
57	Female	6.6	1	Private	No
65	Female	4.4	0	Public	No
76	Male	6.6	1	Public	No
78	Female	6.8	1	Public	No
79	Female	5.4	0	Private	No
82	Female	5.4	0	Private	No
84	Female	6.4	1	Private	No
110	Male	7.5	1	Public	SLT, SE, LD
111	Female	7.5	1	Public	SLT, SE, LD
119	Female	7.2	1	Public	No
153	Male	5.10	0	Public	No
161	Female	5.11	0	Public	No
162	Female	5.11	0	Public	No
163	Female	5.11	0	Public	No
165	Female	5.7	0	Public	No
199	Female	6.3	0	Public	No
206	Male	6.1	0	Public	No
208	Male	5.4	0	Public	No
209	Female	6.1	0	Public	No
317	Male	7.3	1	Public	No

Notes on Table 9.3:

1. 0 under grade represents Pre-primary year
2. SLT means speech and language therapy;
3. SE means special education or teacher assistant.
4. LD means diagnosed learning difficulty
5. Age is in years

Table 9.6:

Students with the lowest measures in three or four scales

ID	VDUCL	VDLCL	VDN	SOLNP	LNS	FCLN	FGLIW	FGNIC
2		√			√		√	√
3					√	√	√	
4					√	√	√	
16					√	√	√	√
20		√					√	√
23						√	√	√
26		√			√		√	√
57			√				√	√
65						√	√	√
76	√			√		√		
78			√			√	√	
79	√			√			√	√
82		√					√	√
84				√		√	√	
110		√				√	√	
111						√	√	√
119				√		√	√	
153					√	√		√
161					√	√		√
162					√	√	√	√
163					√	√		√
165					√	√		√
199					√	√	√	
206					√		√	√
208		√	√				√	√
209	√	√					√	
317				√		√	√	

Notes on Table 9.6:

1. ID means Student Identity Number
2. VDUCL means Visual Discrimination of Upper Case Letters
3. VDLCL means Visual Discrimination of Lower Case Letters
4. VDN means Visual Discrimination of Numbers
5. SOLNP means Spatial Orientation of Letter and Number Pairs
6. LNS means Letter and Number Sequencing
7. FCLN means Form Constancy of Letters and Numbers
8. FGLIW means Figure Ground Letters in Words
9. FGNIC means Figure Ground Numbers in Calculations
10. A √ means that a student was in the group with the lowest measures in the scale so, for example, student number 2 was in the lowest group measures for four of the eight scales

Summary of Students with the Lowest Measures in One or Two Scales

In the lowest student measures, forty-four students scored poorly in one or two of the scales (see Table 9.7). Twenty-one of these students were girls and the remaining twenty-three were boys. Of these students, nine were in Pre-primary, 25 were in Year 1, six were in Year 2 and four were in Year 3, confirming the theory that younger students in lower grades find letter and number reversal recognition more difficult than older students in higher grades. For example, in Pre-primary students are still learning letter and number directionality and find it difficult to identify the correct direction for a letter or number (d h), whereas by Year Three the students are comfortable using letters and numbers and can recognise those that are reversed with ease (dick). Twelve of the 44 students were receiving, or had received some intervention to assist them with learning.

Letter and Number Sequencing was difficult for six of the students with low measures in this group. For example, they had difficulty identifying whether '1372/1732', and 'was/saw' were the same or in a different sequence. Two of these students had additional difficulties with Figure Ground Letters in Words; for example, identifying whether there was or was not a reversed letter in the words presented such as in saw and wald. However, nine students with difficulty in Figure Ground Letters in Words did not display similar difficulties in Letter and Number Sequencing. For example, they were able to identify sequences of letters (was/saw) and numbers (1372/1732) as correct or incorrect, but had difficulty spotting the reversed letter in words such as in: wald. Of the forty-four students in this group, 15 found the individual letters and numbers confusing, but found the letters and numbers in context easier. For example, they were most likely using the context of the word (dib), sequence (was/saw) or calculation (21 ÷ 3 = 7) to give them clues as to the direction of letters and numbers, whereas they had difficulty identifying the direction of a letter or number if it stood alone (L, 9, J and 4) with no contextual clues. In contrast, 24 students found it more difficult to identify letters and numbers in context than to identify the reversed letters and numbers when they were presented individually. For example, these students were able to identify the letters and numbers when presented individually (L, 9, J and 4), but not when given in context (such as in saw and wald, or in 21 ÷ 3 = 7).

Table 9.7:

Characteristics of students with the lowest measures across one or two scales

ID	Gender	Age	Grade	School	Intervention
6	Female	7.5	1	Public	No
7	Male	6.10	1	Public	No
8	Female	7.2	1	Private	No
12	Female	5.9	0	Private	No
19	Female	8.4	3	Public	No
21	Female	8.9	3	Public	No
22	Male	6.3	0	Private	No
24	Male	6.2	0	Private	No
25	Female	5.10	0	Private	No
42	Male	5.10	0	Private	No
46	Female	7.6	2	Private	No
49	Female	7.5	2	Private	No
51	Male	6.4	1	Private	No
58	Female	6.8	1	Private	No
62	Male	6.4	1	Private	No
67	Male	5.4	0	Private	SLT
72	Female	8.2	2	Public	No
74	Male	7.1	1	Public	SLT
75	Male	6.10	1	Public	No
87	Male	6.7	1	Private	SLT, OT
103	Female	6.8	1	Public	No
108	Female	6.5	1	Public	No
113	Female	6.10	1	Public	No
114	Female	7.3	1	Public	No
119	Female	7.2	1	Public	No
139	Male	8.5	3	Public	SE
169	Male	8.1	2	Public	No
201	Male	6.8	1	Public	No
202	Male	5.6	0	Public	No
209	Female	6.1	0	Public	No
223	Male	6.9	1	Public	SLT
224	Male	6.7	1	Public	SLT
229	Male	6.8	1	Public	No
234	Female	6.5	1	Public	No
237	Female	6.11	1	Public	No
268	Male	8.5	3	Public	No
276	Male	5.10	0	Public	SLT
289	Male	8.3	2	Public	LD
297	Male	7.6	2	Public	LD
301	Female	6.10	1	Public	No
303	Male	7.2	1	Public	No
307	Male	7.3	1	Public	SLT, SE
308	Female	7.4	1	Public	SLT
319	Female	5.7	1	Public	SLT

Notes on Table 9.5:

1. 0 under grade represents Pre-primary year
2. SLT means speech and language therapy;
3. SE means special education or teacher assistant.
4. LD means diagnosed learning difficulty

Table 9.8:

Students with the lowest measures in one or two scales

ID	VDUCL	VDLCL	VDN	SOLNP	LNS	FCLN	FGLIW	FGNIC
6					√			
7					√			
8					√		√	
12					√		√	
19						√		
21						√		
22						√	√	
24							√	√
25							√	
42	√							√
46						√		
49						√		
51			√					
58			√					
62	√							
67							√	√
72	√							
74	√						√	
75	√	√						
87								√
103				√				
108						√		
113		√	√					
114							√	
119				√		√		
139			√					
169					√			
201								√
202							√	√
209	√							
223						√		√
224						√		
229				√				
234			√			√		
237							√	
268						√		
276							√	
289					√			
297						√		
301			√					
303				√				
307		√						√
308		√						
319						√		

Notes on Table 9.8:

1. ID means Student Identity Number
2. VDUCL means Visual Discrimination of Upper Case Letters
3. VDLCL means Visual Discrimination of Lower Case Letters
4. VDN means Visual Discrimination of Numbers
5. SOLNP means Spatial Orientation of Letter and Number Pairs
6. LNS means Letter and Number Sequencing
7. FCLN means Form Constancy of Letters and Numbers
8. FGLIW means Figure Ground Letters in Words
9. FGNIC means Figure Ground Numbers in Calculations
10. A √ means that a student was in the group with the lowest measures in the scale so, for example, student number 6 was in the lowest group measures for one of the eight scales

Equating the Eight Scales

For the Four Students with the Lowest Measures

It is possible to equate the separate eight linear scales onto the same linear scale. That is, the separate eight scales can be joined together onto the one linear scale. This is possible because the eight scales are separately linear and have their mean item difficulties each calibrated to zero, and because the same students are used in each of the eight measures. The method used to perform the equating is called the Translation Method (Sadeghi, 2006). The reason for doing this, in this study, is to investigate whether there is any connection across the eight scales for the students with the lowest measures which may give some indication about what these lower ability students have mastered and what they have not mastered. This, in turn, may give an indication about how to help these students and the aspects on which to focus the teaching.

Four students (numbers 27, 80, 81 and 323) had the lowest measures across all eight scales. From the RUMM output, the mean student measures for each of the eight scales can be compared (see Table 9.9). By placing the mean values in decreasing order, the difference between each scale mean and the mean value for Visual Discrimination of Upper Case Letters (the highest mean) can be calculated. This is the Translation Constant that is then added to each of the measures for each of the four students so their measures can be compared. The Translation Constant for each of the eight scales can be calculated in this way (see table 9.9). The measures for the four students, now equated onto the same scale, are set out in Table 9.10 for comparisons.

Table 9.9:

Mean measures in logits for the eight linear scales

	VDUCL	VDLCL	VDN	SOLNP	LNS	FGLIW	FCLN	FGNIC
Mean	2.99	2.68	2.33	2.06	2.05	2.00	1.97	1.29
Translation Constant		0.31	0.66	0.93	0.94	0.99	1.02	1.70

Notes on Tables 9.9 and 9.10

1. VDUCL means Visual Discrimination of Upper Case Letters
2. VDLCL means Visual Discrimination of Lower Case Letters
3. VDN means Visual Discrimination of Numbers
4. SOLNP means Spatial Orientation of Letter and Number Pairs
5. LNS means Letter and Number Sequencing
6. FCLN means Form Constancy of Letters and Numbers
7. FGLIW means Figure Ground Letters in Words
8. FGNIC means Figure Ground Numbers in Calculations

Table 9.10:

Equated measures for the four students with lowest measures over the eight scales

Student	VDUCL	VDLCL	VDN	SOLNP	LNS	FGLIW	FCLN	FGNIC
27	+1.31	+2.32	-0.39	-0.55	-0.93	-4.20	-3.45	-2.41
80	+1.00	+0.57	-0.75	-0.55	-1.99	-4.20	-1.62	-3.25
81	+1.31	+0.57	-0.02	-0.23	-2.53	-4.20	+1.28	-3.25
323	+0.23	-0.97	+0.34	-0.55	-4.28	-4.20	-3.45	-3.25

The data for the four students (numbers 27, 80, 81 and 323 in Table 9.10) are now equated on the same scale and can be directly compared. There is a tendency to have high measures on the left hand side scales and lower measures on the right hand side of Table 9.10. This implies that these four students are better at the visual discrimination of separate numbers or letters than at the mixed numbers or letters, whether they are in pairs or in a context such as a calculation. These students clearly do worse at discriminating letters in words and they are a little better at discriminating numbers in calculations, but they still do not do well at it. This, in turn provides implications for helping these students and implications for teaching.

For the 16 Students with the Lowest Measures over Five/Six Scales

Using the same procedure, with the same Translation Constants for equating as described above, the 16 students with the lowest measures over five or six scales can now be directly compared. The separate measures for the 16 students by scale were taken from the RUMM output and the Translation Constants from Table 9.9 were used to calculate the equated measures for each scale (see Table 9.11). There is a tendency to have high measures on the left hand side scales and lower measures on the right hand side of Table 9.11. These 16 students are better at the visual discrimination of separate numbers or letters than at the mixed numbers or letters, whether they are in pairs or in a context such as a calculation. These students clearly do worse at discriminating letters in words and they are a little better at discriminating numbers in calculations, but they still do not do well at it. The students have very low measures on Figure Grounding Letters in Words (FGLIW); Letter Number Sequencing (LNS) and Form Constancy in Letters and Numbers (FCLN). Their highest measures are in the visual discrimination of letters and numbers (VDUCL, VDCLC and VDN).

Table 9.11:

Equated measures for the 16 students with lowest measures over 5/6 scales

Student	VDUCL	VDLCL	VDN	SOLNP	LNS	FCLN	FGLIW	FGNIC
5	+1.31	+1.44	+2.22	-1.07	-3.34	-0.63	-3.18	-0.11
18	+1.67	+1.24	-1.78	-0.54	-3.34	-0.29	-3.18	-1.55
37	-0.49	+0.70	+1.38	+1.99	-3.34	-2.46	-3.18	-1.55
64	+0.23	-0.03	+1.00	+1.00	-0.83	-1.63	-3.18	-1.55
66	+1.31	+1.06	+1.00	-0.70	-0.64	-0.00	-3.18	-1.55
83	+1.31	+0.88	+2.22	+1.64	+0.67	+0.26	-3.18	-1.55
150	+2.11	+1.06	+0.27	+1.16	-1.98	-2.46	-3.18	+0.33
151	+3.60	+2.09	+0.47	+1.00	-0.83	-1.63	-3.18	-1.55
156	+2.73	+1.64	+1.38	+0.38	-3.34	-2.46	-3.18	-1.55
164	+1.31	-0.48	+1.38	+0.22	-1.98	-2.46	-3.18	+0.68
166	+3.60	+1.24	+1.78	+0.70	-3.34	-2.46	-3.18	-1.55
167	+3.60	+1.68	+1.00	+0.54	-3.34	-2.46	-3.18	-1.55
200	+1.67	+0.53	+0.64	+1.81	+0.80	-1.63	-3.18	-0.11
203	+1.67	-0.68	+2.73	+0.54	-2.54	-2.43	-3.18	-1.55
205	+2.11	+0.53	+1.00	+0.70	+1.77	+0.26	-3.18	-0.11
324	+1.32	+1.24	+1.38	-0.81	-3.34	-2.43	-3.18	-1.55

Notes on Tables 9.11

1. VDUCL means Visual Discrimination of Upper Case Letters
2. VDLCL means Visual Discrimination of Lower Case Letters
3. VDN means Visual Discrimination of Numbers
4. SOLNP means Spatial Orientation of Letter and Number Pairs
5. LNS means Letter and Number Sequencing
6. FCLN means Form Constancy of Letters and Numbers
7. FGLIW means Figure Ground Letters in Words
8. FGNIC means Figure Ground Numbers in Calculations

Summary of Findings

Linear student measures on eight scales relating to students' abilities involving identification of number and letter discriminations and reversals were created using the RUMM2020 Program (Andrich, Sheridan & Luo, 2005) and used to draw valid inferences about students' abilities to discriminate numbers and letters separately, in context and with reversals. The students who scored poorly in all the scales were all in Pre-primary and possibly still learning their letters and numbers. Students who scored poorly on five or six scales had some difficulty with reversed letters and numbers in context and less difficulty with reversed letters and numbers presented individually. Students scoring poorly in one to four scales displayed more difficulty in the contextual letter and number identification rather than the individual letters and numbers. These children may need extra assistance to improve this skill.

The main inferences made are that it is easiest for students to discriminate individual letters and numbers, while letters and numbers used in the context of words, sequences and calculations was more difficult for students to identify. The ratio of boys to girls in these lowest student measures was relatively even, despite the girls scoring higher overall in the scales and the statistical, significant difference with girls scoring higher than boys in Visual Discrimination of Numbers Scale and the Figure Ground Numbers in Calculations. It was expected that the poorest student measures would occur at the younger ages and grades with few Year 2s and Year 3s falling into this category. Students with the lowest scores were those who had most difficulty recognising reversed letters and numbers when presented individually, in sequences, in a variety of fonts, in words or calculations.

The next chapter presents the discussion and implications derived from the findings in the data analysis chapters. Discussion and implications for further research relating to letter and number reversal recognition will also be presented.

CHAPTER 10

DATA ANALYSIS (PART FIVE)

STUDENT INTERVIEWS

In the previous chapter, the common factors relating to the students with the lowest measures on the eight, uni-dimensional linear scales of letter and number discriminations and reversals were discussed. In order to try to better understand the students' own reasoning for their poor letter and number discrimination and recognition, eleven randomly selected students with the lowest measures were interviewed for the pilot study and nine for the main study to see how they explained their own thinking and reasoning in working out the answers to letter and number recognition (known as meta-cognition in the literature). This chapter thus presents the responses given by the students and a qualitative analysis of these responses, resulting in the study benefiting from the strengths of both qualitative and quantitative research methods, known as mixed-methods research in the literature (Greene & Caracelli, 1997; Mertens, 2005; Punch, 2005). Mixed-methods research has become more popular in the last 15 years and is now more widely used and accepted. In the present study, the previous Rasch analyses cannot provide all the answers as to how students learn and think about their learning and student interview data analysis can be very helpful to our understanding relating to letter and number discrimination and recognition. Do these low-scoring students think about their own thinking on letter and number discrimination and recognition and, if so, how and what do they think?

All accepted ethical procedures were complied with. The school Principals, the parents and the students all gave written consent before the students took part in both the pilot interviews (N=11) and the main interviews (N=9). They were told the reasons for the study and it was hoped that their interview comments would help both them and other students to learn their letters and numbers better in the future.

Pilot Study

An initial pilot study was conducted on eleven students to trial questioning techniques and question wording. The initial eleven students' demographics are presented in Table 10.1. These interviews were not recorded and transcribed, however, field notes were taken during the interviews in order to improve questioning and effective data collection in the final interviews. These eleven students were interviewed in two groups; one group of five and one group of six. From this pilot study it was evident that this size group was too large for young students to work in during interviews as some students were able to express themselves and other students remained silent. So an immediate question was: do students who remain silent think about their letter and number discrimination and recognition problems and not say anything, or do they not think about their problems but of something else and say nothing. Further questioning led to the view that most of the silent ones (although not all) do not think too deeply about their problems on these issues. They just think about something else and 'move on'. The students who speak out seem to do some self-analysis and thinking about their learning, but even most of these do not seem to be involved with any deep thinking. This implies that teachers should encourage even young students to think more about how they learn and what they learn.

This observation led to the recorded interviews being conducted in pairs and individual students rather than groups. It was also noted that these young students in Pre-primary had difficulty expressing themselves verbally and this resulted in a slightly older group being chosen for the final interviews.

Table 10.1:

Demographic characteristics of the students in the pilot study

ID	Gender	Age	Grade	School	Intervention
64	Female	4.10	0	Private	SLT
67	Male	5.4	0	Private	SLT
81	Female	5.9	0	Private	No
323	Male	5.8	0	Public	Therapy + assistance
151	Male	5.9	0	Public	No
203	Male	5.7	0	Public	No
205	Female	5.5	0	Public	SLT
153	Male	5.10	0	Public	No
208	Male	5.4	0	Public	No
156	Male	5.11	0	Public	No
67	Male	5.4	0	Private	SLT

Note:
1. Age is in years,
2. 0 under grade represents Pre-primary year,
3. SLT means speech and language therapy;

The initially planned questions for the students are given below. The questions were planned to flow from the Rasch analysis and provide further information that could not be gained from the Rasch analysis. It was expected that these would be 'starter' questions so that further questions could be asked that followed on from the student answers to gain a fuller 'picture' of their thought processes. This, however, proved to be very difficult because some students couldn't always say why they found letter and number discrimination and recognition difficult. It appeared that some of them didn't think deeply about their own thinking (they were not meta-cognitive aware).

1. Which part was most difficult for you?
2. What made this part difficult for you?
3. Which part was the easiest for you?
4. Why do you think this part was easy for you?
5. Some of the other children found these letters difficult (Indicate reversed letters: C, J, B, F, S, R, Z, H, L, N, J, D). Why do you think they found these letters difficult?
6. Some of the other children found these letters difficult (Indicate reversed letters: j, r, f, b, y). Why do you think they found these letters difficult?

7. Some of the other children found these letters difficult (Indicate reversed 5, 2, and unreversed 7, 3, 8). Why do you think they found these letters difficult?
8. What do you think when you try to work it out? / How do you work it out?

During the pilot study with the eleven students, it was observed that the students did not find these questions easy to respond to and the wording was changed. Fewer questions were also set for the students as a lead into extended questioning dependant on each student's responses.

Data Collection

The final interviews (N=9) were conducted in two pairs, two individual interviews and one group of three by the researcher on the school premises for approximately 30 to 45 minutes. The interviewees' responses were recorded and later transcribed. It was made clear to the students prior to the interviews in language appropriate for the age group, that this was to assist the researcher to understand other students who had difficulty recognising letters and numbers, and that there would be no record of who was involved once the data was analysed.

From the pilot study, the questions were revised and fewer questions were planned. The final questions consisted of:

1. I am trying to understand how students/children work out whether letters (numbers/words) are correct or wrong, so that I can make this easier for the students/children to learn their letters (numbers/words). Some students/children found these letters (words or numbers) that I have marked in green difficult. Can you look at them and tell me why you think these students found these letters (numbers/words) difficult? It can be any reason whatsoever.
2. What makes these letters (numbers/words) difficult to decide on?
3. What do you do or how do you think in your brain to work out which ones are right and which ones are wrong when you get muddled up?

Any response given by the students was followed up with appropriate questions or paraphrasing in an attempt to clarify what the students had said. An attempt was also made to convert or translate non-verbal cues or demonstrations given by the students into language for clarification on the recording so for example when a student stated "that letter should go that way", the researcher interpreted it as "so, you say that (name the letter) should face towards the right?"

Student Demographics

A sample of nine students Year One and Year Two were invited to take part in interview focus groups. This was a convenience sample taken from the students who were in Pre-primary and Year One when they participated in the original data collection for the eight variables: (1) Visual Discrimination of Upper Case Letters, (2) Visual Discrimination of Lower Case Letters, (3) Visual Discrimination of Numbers, (4) Spatial Orientation of Letter and Number Pairs, (5) Sequencing of Letters and Numbers, (6) Form Constancy of Letters and Numbers, (7) Figure Ground Letters in Words and (8) Figure Ground Numbers in Calculations). The group was divided into four focus groups: one group of three and three groups of two students. Their ages ranged from six years and eleven months to seven years and seven months at the time of the interview (see Table 10.2). Six girls and three boys agreed to be interviewed. They were all from public schools and two had previously been identified as having difficulty learning and had received therapy or assistance at school.

Table 10.2:

Demographic characteristics of the students in the focus groups

ID	Gender	Age	Grade	School	Intervention
011	Female	7.7	2	Public	No
308	Female	7.6	2	Public	No
313	Male	7.7	2	Public	No
318	Female	7.6	2	Public	Therapy + assistance
320	Male	7.1	2	Public	Therapy + assistance
321	Male	7.3	2	Public	No
330	Female	6.11	2	Public	No
334	Female	7.3	2	Public	No
335	Female	7.6	2	Public	No

Note:
1. Age is in years,
2. 0 under grade represents Pre-primary year,
3. SLT means speech and language therapy;

Data Analysis

Student responses were analysed using the Miles and Hubermann (Punch, 2005) approach. This involved reduction of data by editing the transcripts, and summarising the content. This data were compared (data display) for common threads or themes in the comments which were then coded, despite the young age of the students interviewed and their difficulty in expressing their opinions in depth. The responses these students gave were sometimes thus superficial and general, but some deductions (conclusions) were drawn from what they said and implied and these could then be verified by other students' comments and the data collected in the scale administration. From analysis of the data, it appears that the more capable students were more confident and did not think that they had difficulties, so they were unable to predict why others would have found the work difficult. The students who found the letter and number discrimination and recognition the most difficult appeared to find my questions difficult and were often unable to explain why they had difficulties in their letter and number discrimination and recognition. They appeared less meta-cognitively aware than those who found the tasks easier. The information derived from the interviews is summarised below and some data are displayed in quotes.

Visual discrimination scales

Three students in the pilot study reported that they found the Visual Discrimination of Upper Case Letters easiest to recognise because the print was big so it is easy to identify the letters that are incorrect. One student in the pilot study felt that Visual Discrimination of Lower Case Letters was the easiest because it was ‘really big’. One student said he found that Form Constancy of Letters and Numbers was the easiest, because ‘it was smaller’, but he had not understood the instructions even when demonstrated, thus this comment cannot be used in analysis. One student found the Spatial Orientation of Letter and Number Pairs easiest because he could look at both options to work out which one was correct.

Generally the students found it difficult to think why other students would find certain letters difficult to identify, however, comments were made that the reversed J (ᒧ) looked like an L and that the H may be turned to represent an I or may be seen as two L’s. In the focus group pairs, the students agreed that the upper case letters that were difficult were due to the fact that they were in the reversed orientation (backwards). One student suggested that students may have found the letters difficult because “they could have thought it was a different letter without thinking” and another student thought that others may have found some letters difficult because:

> “they haven’t learned, they are not very good at their letters and it looks different to them (sic). They didn’t learn them like the way its (sic) backwards and they forgot” (student number 335)

These statements suggest that these students think that they rely on what they are taught with regards to the exact font when they are learning letters and that changing the font from what they are familiar with may result in directional confusion and difficulty in discriminating and recognising letters (and presumably numbers).

With regards to Visual Discrimination of Lower Case Letters, the main theme commented on by the students was the letter formation of a number of letters. For example, the reversed letter ‘j’ (ᒧ) could be mistaken for an ‘ɩ̇’, and the formation of the letter ‘r’ (٢

/r) was said to be incorrect in either direction. Some students reported that they had been taught the open ‘b’ (b), while others had been taught the closed ‘b’ when they were asked how they worked out the correct answer, some students were of the opinion that it was how they were taught while others suggested that they used environmental clues, and others ‘felt’ which way the letter had to be written by writing it in the air. These comments suggest that the way in which students are taught to form their letters may influence their susceptibility to reversing letters when they attempt to discriminate them. It also implies that young students tend to use incorrect mental comparisons when analysing letters and numbers depending on their previous experience with the font and shape of letters and numbers, for example associating the ‘j’ with ι and the reversed ‘j’ (l).

When questioned about visual discrimination of numbers, the students felt that the ‘7’ did not “look right” even in the correct orientation. This may be an effect caused by the font used to print the numbers. One student felt the reversed number ‘5’ (Ƨ) was difficult to identify as the student said “I always do my 5’s like that…because it’s easier”. Other students referred to the reversed 2’s as swans and similar to ‘s’ and concluded that other students think it is correct “because they get confused or like it that way”. Other numbers identified as problems included the ‘7’ and ‘8’. The students indicated that the 7 did not “look right” because the students “might think it’s like half a rectangle or square” and the 8 was upside down as the two circles should be directly above each other. The student’s comments about the shape of the numbers links in with the font used to create the numbers, and suggest that this font should be revised. In addition, it appears that students who have difficulty remembering the orientation of numbers look at the shape of the number to find clues as to the formation, rather than developing strategies to assist in the discrimination of the numbers. This was confirmed by comments that they just practise until they know it, or that they “just know it” or that some students may “learn it wrong and forget”, but that no student used cues or ‘tricks’ to work out how to write the numbers of which they were unsure.

Spatial Orientation and Sequencing Scales

Questions relating to the difficulty of Spatial Orientation of Letter and Number Pairs produced little insight into how young students think problems through when they are working out in which direction a letter or number should face. This indicates that some young students, at least, do not engage meta-cognitively in relation to letter and number discrimination and recognition in the early stages of their learning. Maybe they should be directed to think about how and what they learn directly, in their early years.

Three students commented on the fact that when a correctly oriented letter is close to an incorrectly oriented letter, then it becomes difficult to identify. This was explained by one student as:

> "there is (sic) two of the same thing and they look the same but they might have had trouble of (sic) telling which one was the right way". (Student number: 335)

In addition, the proximity of the letters appeared to confuse some students as seen in the comment by one of the students:

> "and those are close because ones on that side and ones on that side and its too difficult". (Student number: 308)

Having the dual orientation of the letters and numbers together may be a confusing factor for some students; however, other students found it easier as they were able to compare the options prior to committing to a response.

Letter and number sequencing were identified as being more difficult as there was a lot of writing on the page and the font was smaller, making it difficult for young students to identify the letters and numbers, as reflected in one student's comment:

> "That writing gets bigger and smaller and the other one darker and can't really read it because it goes (sic) too close". (student number: 321)

This suggests that the layout of the letter and number sequencing during initial learning could be improved in order to assist students in identifying the individual letters and numbers in a sequence (and perhaps in the actual questionnaire used in the present study).

Form Constancy and Figure Ground Scales

A number of students expressed the opinion that identifying reversed letters within words was difficult due to levels of reading and spelling ability, so that some students may read ate as "eat" and identify it as incorrectly spelled but did not identify the reversed "t". A similar point was made about words with a silent "e" at the end such as come, where students felt that the lower scoring students thought it was incorrect as it should have been spelt without the "e". This would imply that both spelling and reading ability are related to the tendency to reverse letters when they appear in words.

When the students were presented with the numbers in calculations they were in agreement that students would find this difficult if they had not yet learned their multiplication and division operations yet and that the layout of some of the calculations in the vertical orientation would also make it more difficult for students to identify the reversed letters. Some students found the Figure Ground of Numbers in Calculations difficult because "it looks like adding up. It looks really hard" and "because they are sums I don't know" (student number: 151, 330, and 205). The students also commented on the possibility of other students working too quickly and not identifying the operation correctly and therefore indicating that the answer is incorrect, even when there is no reversed number in the solution to the calculation. This implies that the layout of calculations, as well as the level of attention the students give to the work, may influence their ability to correctly identify and respond to set calculations.

General comments

With regards to which section was most difficult, two students in the pilot study stated that everything was really difficult because "I don't know which one is right and which one is wrong" and "because all are the wrong way around" (student numbers: 67 and

81). One student said nothing was difficult because it "just is easy" (student number: 64). Two students found the Form Constancy of Letters and Numbers difficult because "it was too small and the letters muddle me up" and "it is confusing because there is too much on the page" (student numbers: 203 and 153). A third student identified Form Constancy of Letters and Numbers as difficult but he had not understood the instructions, even after demonstration and repetition (student number: 323). In addition, three students found the Figure Ground Letters in Words difficult because of "the way they were written", because they were tired, or because they thought that all the letters were upside down (student numbers: 156, 208 and 323).

Comments on How to Overcome the Confusion

In general, some students found it difficult to identify how they worked out which letter or number was correct and these students showed little evidence of any meta-cognitive processing. Some students used immature mental comparisons by using a global rule that all the "right letters face that way (pointed right) and all the wrong letters face that way (pointed left)". However, some students did use some 'objective' assistance in working out their letters and numbers, including using the index finger and thumb at right angles to each other to identify which way an "L" faced, using environmental cues around the classroom, creating mental pictures of the letters and writing them in the air to "feel" which one was right.

Summary of Findings

From the interviews with the students and the analysis of their comments, the following conclusions were drawn.

1. Some weak students showed little evidence of using any meta-cognitive processing and did not appear to think about their learning problems (and how to overcome them) in regard to discrimination and recognition of letters and numbers;

2. Some weaker students thought that "they just learnt the letters and numbers" (you just look at the letters and numbers, and you know what is correct and what is wrong) or you didn't learn them;

3. Young students appear to find letters and numbers harder to discriminate and recognise in some fonts than in others, for example the 'ball and stick' fonts such as D'Nealian style, Report and Folder are clear, bold and easy for many students to read compared to the more elaborate cursive writing styles such as Victorian Modern Cursive and Queensland Beginners;

4. The page layout appears to influence the ability of some weaker students in regard to discrimination and recognition of letters and numbers. This would also be of importance when setting out worksheets for students in class, as they would probably find it difficult to perform at their best if the page was too full and the words too close. In addition, creating a uniform font to use in both the reading and writing books for young students who are weak in reading and numbers may be of the greatest benefit to their learning;

5. The present study may need to be repeated with some different fonts and that the layout of the questionnaire pages in the present study should be reviewed, especially on pages where there was a lot of writing; and

6. It was noticeable that the students did not seem to have been given many modes of 'objective' assistance which they could use to correct themselves when they were unsure of letter and number direction. Added to this need to develop strategies, is the complication of students not using the correct starting points when forming letters and numbers and this seems to have added to their confusion when there was uncertainty.

The next chapter, Chapter Eleven, answers the research questions and provides a discussion of findings and implications for the present study.

CHAPTER ELEVEN

SUMMARY, DISCUSSION AND IMPLICATIONS

This chapter summarises the study within the context of the questions posed in Chapter One. It draws together the major quantitative and qualitative findings from the data and relates these findings to the relevant literature. In the latter part of this chapter, the implications of these findings for the teacher, student, therapist and future research are outlined.

Summary of the Study

Six research questions were presented in Chapter One. These questions outlined the core purposes of the present study: to use an appropriate model of visual perceptual letter and number identification relating to six operationally defined visual perceptual concepts (visual discrimination, visual spatial orientation, visual form constancy, visual sequencing and visual figure ground) to guide the creation of eight uni-dimensional linear scales to measure these constructs in primary school children. Questionnaires (instruments) for the eight scales were developed and adjusted according to suggestions from a focus group of occupational therapists (N=6) working in the field with school-aged students. Data were collected from three sources: (1) the eight questionnaires on visual perceptions of letters and numbers instruments administered to young students (N=324); (2) field notes taken about what children said during the questionnaire administration (N=11); and (3) Focus Group interviews of students (N=9) some months after the questionnaire data collection.

The questionnaire data from the visual perception of letters and numbers were collected over a five month period from August to December 2008 and were analysed with the RUMM2020 computer program (Andrich et al., 2005) to create eight linear, uni-dimensional scales. These eight scales were Visual Discrimination of Upper Case Letters, Visual Discrimination of Lower Case Letters, Visual Discrimination of Numbers, Spatial Orientation of Letter and Number Pairs, Letter and Number Sequencing, Form Constancy of Letters and Numbers, Figure Ground Letters in Words and Figure Ground Numbers in Calculations. The qualitative data from the student Focus Group were collected early in 2009 and were analysed using the Miles and Huberman Analytic Framework (M. Miles & Huberman, 1994; Punch, 2005).

Answering the Research Questions

Research Question One

Can a model of visual perceptual letter and number identification be created according to five operationally defined visual perceptual concepts (visual discrimination, visual spatial orientation, visual form constancy, visual sequencing and visual figure ground) to guide the creation of eight uni-dimensional linear scales to measure these constructs?

A model (see Chapter Three) was conceptualised to guide the development of the visual perception- based measures of letter and number reversal recognition (Richmond, 2008). This model was guided by a combination of the conceptual frameworks of visual information processing as described by various authors (Gibson, 1969; Tsurumi & Todd, 1997), models of perceptuo-motor function (Kephart, 1960; Myers & Hammill, 1982; Penso, 1992) and the theoretical models of letter and number reversal (Ayres, 1978; Brendler & Lachmann, 2001; Kephart, 1960; Lachmann & Geyer, 2003; Landy & Burridge, 1999; Lane, 1988; Lee, 2006; Todd, 1999; Zaba, 1984). The model of visual, visual perceptual and visual motor skills (from which the eight scales of visual perceptual letter and number reversal recognition were developed) (Richmond, 2008) recognised the importance of three levels of information processing involved in letter and number recognition. These levels were: (1) input from one of the senses or from a cognitive goal, (2) 'through-put' (processing) of information as in perceiving or understanding the stimulus and (3) output which involves a written or verbal response. In this model, the prerequisites of 'throughput' (processing) are visual attention, visual discrimination and visual memory. Visual discrimination was used in the first three scales and was related to upper case letters, lower case letters and numbers. The throughput phase involves the intellectual manipulation of the information and may entail using visual perceptual skills of form constancy, figure ground, sequencing and spatial orientation to recognise, form meaningful combinations and replicate letters and numbers. These skills were incorporated in the last five scales. The focus group of occupational therapists working in the field with primary school-aged children revealed general consensus among the therapists that these constructs were appropriate and adequate for assessing letter and number recognition among school-aged children.

Research Question Two

Can linear, uni-dimensional measures of letter and number recognition related to Visual Discrimination of Upper Case Letters; Visual Discrimination of Lower Case Letters; and Visual Discrimination of Numbers be created so that they are reliable and valid inferences can be drawn from them?

This research question was addressed in Chapters Four and Six. In Chapter Four, three separate, uni-dimensional scales were conceptualised where the items were ordered from easy to hard so that the student measures could be conceptualised on the same scale from low to high. In Chapter Six, the data relating to the three scales were analysed separately with the RUMM2020 computer program to create three linear, uni-dimensional scales. The final scale for Visual Discrimination of Upper Case Letters (VDUCL) contained 18 items. There was a good fit to the measurement model (item-trait interaction chi-square = 42.07, df=94, p=0.23) showing that there was satisfactory agreement about the difficulties of the 18 items along the scale; all items fitted the model with p>0.10, and the standardised fit residual statistics had a distribution with a mean near zero and a standard deviation near one, supporting the good fit. This means that one parameter could be used for each student (as a measure of ability) and one parameter for each item (as a measure of difficulty) and that these parameters will predict with reasonable accuracy each student's response to each item. In the Rasch measurement model, this is what is needed to create a uni-dimensional scale. This scale was, however, not as reliable as desired. The Student Separation Index was 0.55 (somewhat low), meaning that the measures were not as well separated in comparison to the errors as desirable and the Cronbach Alpha Coefficient of Reliability was 0.69 (also somewhat low). This means that some caution would be needed in relation to drawing inferences for action from this scale and, it would be desirable to improve the reliability of this scale for any future use of it. The inferences that could be drawn relate to the order of item difficulties (see Table 6.5) and those students having the most difficulty in discriminating upper case letters (see Table 6.8).

The final scale for Visual Discrimination of Lower Case Letters (VDLCL) contained 31 items. There was a good fit to the measurement model (the item-trait interaction chi-square = 136.85, df=96, p=0.20) showing that there was satisfactory agreement about the difficulties of the 31 items along the scale; all items fitted the model with p>0.08, and the standardised fit residual statistics had a distribution with a mean near zero and a standard deviation near one, supporting the good fit. The Student Separation Index was 0.82 (satisfactory), meaning that the measures were reasonably well separated in comparison to the errors and the Cronbach Alpha Coefficient of Reliability was 0.82 (satisfactory). This means that valid inferences could be drawn from this scale, specifically, the order of item difficulty (see Table 6.6) and the lowest student measures (see Table 6.9).

The final scale for Visual Discrimination of Numbers (VDN) contained 14 items. There was a good fit to the measurement model (the item-trait interaction chi-square = 68.76, df=85, df=92, p=0.12) showing that there was satisfactory agreement about the difficulties of the 14 items along the scale; all items fitted the model with p>0.05, and the standardised fit residual statistics had a distribution with a mean near zero and a standard deviation near one, supporting the good fit. The Student Separation Index was 0.75 (satisfactory), meaning that the measures were reasonably well separated in comparison to the errors and the Cronbach Alpha Coefficient of Reliability was 0.75. This means that valid inferences could be drawn from this scale, specifically, the order of item difficulty for this scale (see Table 6.7) and the lowest student measures (see Table 6.10).

Inferences Drawn in Relation to the Three Scales

The creation of the uni-dimensional and reliable scales now allows for inferences to be drawn from them. The lowest scoring students in Visual Discrimination of Upper Case Letters displayed difficulty in discriminating letters that were asymmetrical around the vertical axis, and this applies to reversed upper case asymmetrical letters as well, for example L and ꓘ.

Students with the lowest measures in Visual Discrimination of Lower Case Letters found it difficult to discriminate most of the lower case letters with only a body such as the a and s, as well as the letters with a body and tail, such as g, ʒ, and q. They also had difficulty with the discrimination of lower case letters presented in the reversed orientation such as ɿ, ɟ and ʞ. Students with the lowest measures for Visual Discrimination of Numbers were unable to identify, or discriminate, any of the reversed numbers in the scale Ɛ and ٦, as well as the number 9 and its reversal ᑭ.

The easiest letters and numbers for students to discriminate were the T, X, Y, k, h, b, 1 and 8, while the most difficult letters and numbers for students to discriminate were ꟼ, ꓘ, Ǝ, ɘ, ꟼ, ʞ,and the number Ɛ. Girls scored higher than boys in all three scales, but this was only statistically significant for the Visual Discrimination of Numbers Scale. Students in Public Schools scored higher than those in Private Schools in all three measures, but only the measure of Visual Discrimination of Upper Case Letters was statistically significantly different. There was a statistically significant difference in the performance of students as their age and grade increased (as expected), with younger students in lower grades scoring significantly lower than the older students in the higher grades for all three scales. This is also evidence supporting the validity of the scales. Students with the lowest scores were those who had most difficulty discriminating reversed upper case letters. These findings are in line with the literature which indicates that visual discrimination assists in the visual differentiation between symbols, words and changes in position and allows the person to make sense of the written word (Kirk et al., 2000; Schneck, 1996; Todd, 1999).

The findings for visual discrimination of upper case letters, lower case letters and numbers allow teachers to objectively identify the letters and numbers that students find difficult to discriminate. Those students who have poor discrimination skills of letters and numbers are easily identified so that tailored teaching can be applied to those in need.

Research Question Three

Can linear, uni-dimensional measures of letter and number recognition be created that relate to Spatial Orientation of Letters and Numbers and Letter and Number Sequencing so that they produce reliable measures from which valid inferences can be drawn?

This research question was addressed in Chapters Four and Seven. In Chapter Four, two separate, uni-dimensional scales were conceptualised where the items were ordered from easy to hard so that the student measures could be conceptualised on the same scale from low to high. In Chapter Seven, the data relating to the two scales were analysed separately with the RUMM2020 computer program to create two linear, uni-dimensional scales. The final scale for Spatial Orientation Letter and Number Pairs (SOLNP) contained 27 items. There was a good fit to the measurement model (the item-trait interaction chi-square = 77.98, df=0.96 and p=0.57) showing that there was very good agreement about the difficulties of the 27 items along the scale; all items fitted the model with p>0.02, and the standardised fit residual statistics had a distribution with a mean near zero and a standard deviation near one, supporting the good fit. This means that one parameter could be used for each student (as a measure of ability) and one parameter for each item (as a measure of difficulty), including a combination of letters and numbers, and that these parameters will predict with reasonable accuracy each student's response to each item. In the Rasch measurement model, this is what is needed to create a uni-dimensional scale. Two items showed less than ideal fit residuals but their removal did not improve the overall fit to the measurement model. The Student Separation Index was 0.84 (satisfactory), meaning that the measures were satisfactorily separated in comparison to the errors and the Cronbach Alpha Internal Reliability was 0.88 (also satisfactory). This means that it would be desirable to improve the reliability of this scale for any future use of it. The inferences that could be drawn relate to the order of item difficulties (see Table 7.5) and those students having the most difficulty in discriminating letter and number pairs (see Table 7.6).

The final scale for Letter and Number Sequencing (LNS) contained 36 items including letter and number sequences. There was a good fit to the measurement model (the item-trait interaction chi-square = 124.95, df=0.97 and p=0.13) showing that there was acceptable agreement about the difficulties of the 36 items along the scale; all items fitted the model with p>0.03, and the standardised fit residual statistics had a distribution with a mean near zero and a standard deviation near one, supporting the good fit. The Student Separation Index was 0.94 (very good), meaning that the measures were well separated in comparison to the errors and the Cronbach Alpha Internal Reliability was 0.97 (excellent). This means that valid inferences could be drawn from this scale, specifically, the order of item difficulty (see Table 7.5) and the lowest student measures (see Table 7.7).

Inferences Drawn in Relation to the Two Spatial Scales

The creation of the uni-dimensional and reliable scales now allows for inferences to be drawn from them. The lowest scoring students in Spatial Orientation of Letter and Number Pairs displayed difficulty in discriminating upper case letter pairs as well as number pairs, specifically number pairs where the number had a sharp angle such as 4 4, 2 5, and curved letter pairs such as b d, D D and q p. Students with the lowest measures in Letter and Number Sequences found it difficult identifying whether number sequences of more than three numbers (as in 9834/9843) and letter sequences (for example jump/jmup, found/fuond, and laugh/laugh) were the same or not. Sequences where the central letters were reversed or where the reversed letters only consisted of a body were the most difficult for students to recognise as in jump/jmup, and soac/saoc.

The easiest letter and number pairs for students to discriminate were the: d h, k d, and d b, while the most difficult letters and numbers for students to discriminate were 3 Ɛ, 3Ɛand q p. Girls scored higher than boys in both scales, but this was only statistically significant for the Letter and Number Pairs Scale. Students in Public Schools scored higher than those in Private Schools in both measures, but these measures were not statistically significantly different. There was a statistically significant difference in the performance of students as their age and grade increased (as expected), with younger students in lower grades scoring significantly lower than the older students in the higher grades for both scales. Students with the lowest scores were those that had most difficulty discriminating reversed lower case letter pairs and letter sequences. These findings are in line with the literature which indicates that students who have difficulty in the mechanics of spelling, reading and mathematics display poor spatial and sequencing skills (Catts & Kamhi, 1999; Cherry et al., 1989; Chinn, 2002; Green & Chee, 1997; Kulp, 1999; Schneck, 1996; Silver, 2001).

The findings for Spatial Orientation of Letter and Number Pairs as well as Letter and Number Sequencing allow teachers to objectively identify the letters and numbers that students find difficult to identify in the correct spatial orientation and sequences. Those students who have poor spatial orientation and sequencing skills of letters and numbers are easily identified so that tailored teaching can be applied to those in need.

Research Question Four

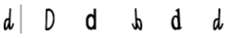
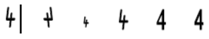
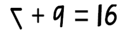
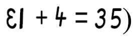
Can linear, uni-dimensional measures of letter and number recognition be created that relate to Form Constancy of Letters and Numbers; Figure Ground Letters in Words and Figure Ground Numbers in Calculations so that they produce reliable measures from which valid inferences can be drawn?

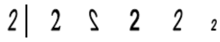
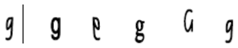
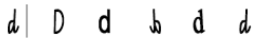
This research question was addressed in Chapters Four and Eight. In Chapter Four, three separate, uni-dimensional scales were conceptualised where the items were ordered from easy to hard so that the student measures could be conceptualised on the same scale from low to high. In Chapter Eight, the data relating to the three scales were analysed separately with the RUMM2020 computer program to create three linear, uni-dimensional scales. The final scale for Form Constancy of Letters and Numbers (FCLN) contained 18 items. There was a good fit to the measurement model (the item-trait interaction chi-square = 69.69, df=0.94, p=0.07) showing that there was satisfactory (but not excellent) agreement about the difficulties of the 18 items along the scale; all items fitted the model with p>0.03, and the standardised fit residual statistics had a distribution with a mean near zero and a standard deviation near one, supporting the good fit. This means that one parameter could be used for each student (as a measure of ability) and one parameter for each item (as a measure of difficulty) and that these parameters would predict with reasonable accuracy each student's response to each item. In the Rasch measurement model, this is what is needed to create a uni-dimensional scale. This scale was shown to be reliable with the Student Separation Index of 0.94 (very good), meaning that the measures were well separated in comparison to the errors. This means that valid inferences can be made from this scale. The inferences that could be drawn relate to the order of item difficulties (see Table 8.5) and those students having the most difficulty in discriminating upper case letters (see Table 8.8).

The final scale for Figure Ground of Letters in Words (FGLW) contained 34 items. There was a good fit to the measurement model (the item-trait interaction chi-square = 117.59, df=0.97, p=0.14) showing that there was acceptable agreement about the difficulties of the 34 items along the scale; all items fitted the model with p>0.06, and the standardised fit residual statistics had a distribution with a mean near zero and a standard deviation near one, supporting the good fit. The Student Separation Index was 0.97 (very good), meaning that the measures were well separated in comparison to the errors. This means that valid inferences could be drawn from this scale, specifically, the order of item difficulty (see Table 8.6) and the lowest student measures (see Table 8.9).

The final scale for Figure Ground Numbers in Calculations (FCNC) contained 15 items. There was a good fit to the measurement model (the item-trait interaction chi-square =58.83, df=0.93, p=0.52) showing that there was very good agreement about the difficulties of the 15 items along the scale; all items fitted the model with p>0.08, and the standardised fit residual statistics had a distribution with a mean near zero and a standard deviation near one, supporting the good fit. The Student Separation Index was 0.95 (very good), meaning that the measures were well separated in comparison to the errors and the Cronbach Alpha Internal Reliability was 0.98 (very good). This means that valid inferences could be drawn from this scale, specifically, the order of item difficulty for this scale (see Table 8.7) and the lowest student measures (see Table 8.10).

Inferences Drawn in Relation to the Three Scales

The creation of the uni-dimensional and reliable scales as established, now allows for inferences to be drawn from them. The lowest scoring students in Form Constancy of Letters and Numbers displayed difficulty in identifying the reversed letters such as: , but were more capable of identifying the reversed numbers such as:  when they were presented in a variety of fonts. Students with the lowest measures in Figure Ground Letters in Words found it difficult to identify most of the words which contained a reversed letter within the word such as , and . Students with the lowest measures for Figure Ground Numbers in Calculations were unable to identify any of the reversed numbers in calculations above 12 (such as ), and they also had difficulty identifying reversed numbers that were part of a larger number, where the reversed number was one of a number greater than 10 (such as ).

It was easiest for students to identify numbers, such as  and the letter ‘a’ when presented in a variety of fonts, while the most difficult letters for students to identify were , and . Girls scored higher than boys in all three scales, but this was only statistically significant for the Figure Ground Numbers in Calculations Scale. Students in Public Schools scored higher than those in Private Schools in all three measures, but only the measures of Figure Ground Letters in Words and Figure Ground Numbers in Calculations were statistically significantly different. There was a statistically significant difference in the performance of students as their age and grade increased (as expected), with younger students in lower grades scoring significantly lower than the older students in the higher grades for all three scales. Students with the lowest scores were those that had most difficulty identifying reversed letters in a variety of fonts as well as reversed letters in complex words and reversed numbers in calculations above 10. These findings are in line with the literature which indicates that students rely on recognition of the dominant features of certain figures (letters and numbers) when they appear in different sizes, shadings, textures and positions (Hammill et al., 1993; Schneck, 1996) and that figure-ground skills are used when calculating a number of values or in reading and writing (Chinn, 2002; Murray-Slutsky & Paris, 2000; Schneck, 1996).

The findings for Form Constancy of Letters and Numbers, Figure Ground of Letters in Words and Figure Ground of Numbers in Calculations allow teachers to objectively identify the letters and numbers that students find difficult to identify in different fonts and in context of words and calculations. Those students who have poor form constancy and figure ground skills of letters and numbers are easily identified so that tailored teaching can be applied to those in need.

Research Question Five

Will identifying the students with the lowest measures and analysis of the common features related to these students allow accurate identification of the letter and number groups requiring additional attention in the early school years and, in addition, will it allow identification of student groups that require early intervention?

The students who had difficulty in seven or eight of the scales displayed difficulties in all areas of letter and number identification related to visual discrimination, spatial orientation, sequencing, form constancy and figure-ground skills, as measured in the present study. The results of these students' responses support the notion that children need to learn to identify individual letters and numbers in the correct, as well as the reversed orientation, prior to being able to manipulate reversed letters and numbers in context. These lowest scoring students were all among the younger students in the lower grades. In addition, two of the lowest scoring students were identified as having learning difficulties on the parent demographics form. This indicates that the scales are identifying accurately students who require additional assistance in learning their letters and numbers.

Forty-seven students had the lowest scores in more than two scales. Among the lowest scoring students, there were 20 boys and 27 girls, suggesting that girls and boys are approximately equally prone to experiencing difficulties learning letter and number recognition and directionality. Of these students, 37 were in the Pre-Primary year, nine were in Year 1 and one student was in Year 3. This indicates (as would be expected), that younger students in the earlier grades have more difficulty learning their letters and numbers than older students in the higher grades. This finding is supported by the literature referring to the developmental progression of students with visual perceptual skills as well as reading, spelling and mathematical concepts related to reversals (Boon, 1986; Cherry et al., 1989; Cratty, 1979; Grove & Haupfleisch, 1978; Hanneford, 1995; Kephart, 1960; Lane, 1988).

Students with the lowest measures found individual letters and numbers such as L, D, j, z, and 9, as well as number and letter reversals, such as ᑫ, ƨ, and ∂, the most difficult. The most difficult letters and numbers to identify in context were those that contained a reversal of a letter or number or where the sequence of the letters was different, such as in dlack, on/no and 21 ÷ 3 = ᒣ. In addition to identifying the letters and numbers which posed the most difficulty for students with low measures, it was also possible to identify students who required additional assistance in the classroom in order to learn their letters and numbers. Nine of the students identified by this research as having some of the lowest measures had already been identified as having difficulty with learning or were receiving additional assistance in the classroom or through therapy sessions. Once again, these results supported the accuracy of the scales in identifying students with problems.

Research Question Six

Can students with the lowest measures accurately identify the reasons why certain letters and numbers in isolation and in context are more difficult for them to identify than other letters and numbers? Can this information add to the pool of knowledge in order to assist students at risk in the area of literacy and numeracy in the early school years?

Responses from students given during interviews were often superficial and general, however analysis of the given data, indicated that the more capable students were more confident, considering their abilities to be good, and they were thus unable to predict why others would have found the work difficult. The students who found the letter and number discrimination and recognition the most difficult appeared to find the interview questions difficult and were often unable to explain why they had difficulties in their letter and number discrimination and recognition. They appeared to have difficulty processing meta-cognitive information, which suggests that teachers may need to give more meta-cognitive ‘concrete’ clues for left and right concepts in letters and numbers for students who are uncertain of their letter and number recognition skills (such as placing the clenched fists together with thumbs extended to form a visual picture of a bed to assist students to identify the ‘b’ and ‘d’).

Students suggested that those who rely on what they are taught with regards to the exact font when they are learning letters may think that reversed letters and numbers or letters and numbers in a different font are actually other letters such as the L and reversed ‘J’ (ᒐ). This alerts teachers to the need to use one familiar font with students who have difficulty discriminating and recognising letters and numbers rather than exposing them to a variety of fonts so as to avoid directional confusion of their letters and numbers. In addition, students found the letters and numbers in context more difficult to identify as they often considered the words to be spelled incorrectly, but did not recognise that the letters may be reversed, as with the word aɟe, which a number of students interpreted as an incorrectly spelled ‘eat’. This results in difficulty for the teacher in being able to identify whether the student has difficulty identifying the reversed letters and numbers or whether the student is reading the words or mathematical calculations incorrectly.

Students were inclined to automatically consider work to be more difficult when the letters and numbers were written in a smaller font size, when there was a lot of writing on a page or when the layout was not familiar to them. Small font size generally resulted in letters in words being closer together which resulted in some students finding it difficult to read as they said the letters joined up or were too close. Similarly, when calculations were written using larger numbers or the vertical layout students thought it was more difficult because they were not used to this presentation and seemed to then be unable to scan for reversed numbers in the group. This suggests that for younger students, using larger fonts with a looser layout and horizontal lines for calculations makes it easier for them to scan and read.

Implications of the Present Study

The results and publication of the present study provides guidelines regarding the development and objective identification and understanding of letter and number directionality, context and sequencing in primary school students. The scales developed in this study will be useful in identifying, accurately and objectively, students who require additional assistance in learning their letters and numbers. This will better equip teachers, parents and educators to apply timely interventions for the lowest scoring students in order to ensure that all students progress to their potential. It will also be possible to judge when a student has a genuine letter and number reversal recognition difficulty or when it is an apparent difficulty related to age and development, as the lowest scoring students tended to be in the Pre-Primary year. More specific implications for teachers, therapists, students and future research are elaborated below with regards to the eight uni-dimensional measures.

Implications for Teachers

Making the results of the outcomes of this study available to teachers allows teachers of primary school students to have access to guidelines regarding the development of understanding of letter and number directionality, context and sequencing. As a result, the inferences drawn from, for example, the Visual Discrimination of Upper Case Letters scale developed in this study will be useful in directing the teachers to the order of item difficulties as well as identifying those students having the most difficulty in discriminating upper case letters and who may require additional assistance in learning their letters and numbers. This will mean that when teachers use this scale in their classrooms they will be able to predict which of the letters their students find the most difficult (such as those that are asymmetrical around the vertical axis like P and K). They will then be better equipped to apply timely and tailored interventions for the lowest scoring students on an individual basis. The information derived from the focus group interviews also provides insights into why some students tend to reverse the letters that are asymmetrical around the vertical axis, as well as identifying the specific letters that are difficult for specific students.

Teachers can assume that the letters which require most attention in the teaching of lower case letters will be those letters that the students with the lowest measures in Visual Discrimination of Lower Case Letters found difficult to discriminate (most of the lower case letters with only a body, letters with a body and tail, as well as letters which can be written in the reversed orientation, such as ɿ, ɟ and ɜ). Teachers can further be led to understand the special attention that must be given to certain numbers by looking at the numbers students found most difficult to discriminate in the Visual Discrimination of Numbers Scale. This scale indicates that students have more difficulty with numbers where the orientation can easily be reversed such as '2' and '3'.

The scales for Visual Discrimination of Upper Case Letters, Visual Discrimination of Lower Case Letters and Visual Discrimination of Numbers can be administered to a student when the teacher suspects that the student is having difficulty discriminating letters and numbers. The scales can be administered to individual students or in a whole class group to save time for the teacher. The student is required to identify the letters and numbers that are presented in the incorrect/reversed orientation. Confusion of correctly oriented letters and numbers or failure to identify incorrectly oriented letters and numbers indicates difficulty in discriminating letters and numbers in single presentation. The results from the administration of these scales would then allow the teacher to tailor individual letter and number teaching to individual students so that the teaching is efficient in terms and time, content and emphasis.

The scales Spatial Orientation of Letter and Number Pairs (SOLNP) and Letter and Number Sequences (LNS) allows for inferences to be drawn about those letters and numbers that cause the most difficulty with orientation for the lowest scoring students (including upper case letter pairs as well as number pairs where the number had a sharp angle and curved-letter pairs). For students with the lowest measures in LNS, the number sequences with more than three numbers and letters where the central letters were reversed (such as in riɡht), or where the reversed letters only consisted of a body such as onɔe, were the most difficult. These scale data will direct teachers in choosing appropriate sequence lengths when teaching individual students. The scales are also indicative of certain spelling words that may be more difficult to remember because they contain letters that are difficult to identify in the sequence of letters forming the word, such as those words where the central letters consist of only a body as in ‘jump’ and ‘can’. Teachers can therefore be aware that when students display difficulty with discriminating reversed lower case letter pairs and letter sequences, it may translate into difficulty in the mechanics of spelling, reading and mathematics. Thus when the individual student’s areas of difficulty are identified and addressed with regards to spatial orientation and sequencing, then the student may find the mechanics of mathematics, spelling and reading easier to master.

Three uni-dimensional and reliable scales created for Form Constancy of Letters and Numbers (FCLN), Figure Ground Letters in Words (FGLW) and Figure Ground Numbers in Calculations (FGNC) allow for inferences to be drawn that relate to the student’s ability to use various fonts and to find letters or numbers when embedded within the context of the work. The lowest scoring students in Form Constancy Letters and Numbers displayed difficulty in identifying the reversed letters (such as the reversed ‘d’ in d| D d b d d) but were more capable of identifying the reversed numbers when they were presented in a variety of fonts (such as the reversed ‘2’ in 2| 2 S 2 2 2). This points teachers towards the small differences in the font style of writing numbers, and a greater variation in font style of letters which may confuse students. Keeping this in mind when creating programs to use in the classroom may assist teachers to produce a higher standard of teaching when dealing with students who have the lowest measures on this scale.

Teachers can use the outcomes of the Figure Ground Numbers in Calculations Scale to support the argument that younger students or students with figure-ground difficulty should be given the opportunity to work with smaller numbers (below 10) until they are confident in the use of individual numbers before they are expected to work with larger numbers. There is also evidence that students who have learned to calculate numbers horizontally may have more confusion when presented with similar numbers in the vertical orientation. Teachers would have to be aware of the earlier teaching methods in lower grades to enable students to use their potential in their current setting. It must be emphasised that the results indicate that figure ground difficulties are quite common in lower grades, but may improve as the student matures. Choosing appropriate fonts and layout for students will be very helpful to promoting student learning.

Identifying the types of letters and numbers that students found most difficult, as well as the contextual difficulties students experienced, will provide teachers with insight into the type or style of learning an individual student is using. It would thus be advisable for teachers who have students with low measures on these scales to concentrate on directionality and letter form, as well as context, when teaching these students letters and numbers. Less time can also be spent on teaching letters which students found easiest to discriminate such as the capital letters that are symmetrical around the vertical axis (A, H, I, M, O, T, U, V, W, X, Y) and more time on the letters that students found most difficult, such as the lower case letters that consist only of a body (a, c, e, i, r, s, u, v, w, x, z).

Implications for Students

Students who complete these measures will provide information for their teachers or therapists which will guide the planning of their learning and therapy programs. Students with the lowest measures will be identified as those who may benefit from assistance in the classroom to learn certain letter and number identification skills. As a result, the inferences drawn by the teacher or therapist from, for example, the Visual Discrimination of Upper Case Letters Scale developed in this study will result in accurate identification of those upper case letters that the specific students find most difficult. These students can then target their learning to these specific letters such as the direction of the upper case letters that are asymmetrical around the vertical axis. This may be approached in a number of ways through different teaching methods, encouraging left and right discrimination on a two dimensional level or by supplying appropriate visual or verbal prompts. Similarly, students can be directed to spend more time practising the lower case letters which they found most difficult in Visual Discrimination of Lower Case Letters such as the letters with only a body (c, r, s), letters with a body and tail (y, g, q, p), as well as letters which can be written in the reversed orientation (b/d, p/q, n/u). Students can also be directed to certain numbers that they need to pay more attention to when writing or reading, as these will be the numbers that they found difficult to discriminate in Visual Discrimination Numbers such as the 5 (Ƨ), 7 (ᒣ), 3 (Ɛ). These visual discrimination scales will guide the students to the letters and numbers they find difficult, which will allow for adequate and effective attention to the specific letters and numbers and result in faster learning and overcoming their areas of difficulty.

The outcomes of Visual Discrimination of Upper Case Letters, Visual Discrimination of Lower Case Letters and Visual Discrimination of Numbers can be used to give a student clues as to how to remember to form the letters and numbers and how to remember the directionality of letters and numbers that they are finding difficult. In this way, the student may then be encouraged to create their own "picture in their head" as was described by some students in the interviews, or other visual or verbal cues that may be adopted by the student, such as holding the index finger and thumb up to see which way an upper case letter L was meant to be. When students are confident in the discrimination of individual letters and numbers, they are able to use that information in combinations and in various contexts with confidence.

The Spatial Orientation of Letter and Number Pairs Scale (SOLNP) and the Letter and Number Sequences Scale (LNS) allow for inferences to be drawn indicating which letters and numbers cause the most difficulty with orientation for the lowest scoring students (upper case letter pairs as well as number pairs where the number had a sharp angle and curved letter pairs). Similarly, students with the lowest measures in Letter and Number Sequence indicate that number sequences of more than three numbers and letter sequences where the central letters were reversed (such as: jump jmup), or where the reversed letters only consisted of a body (such as: soac saoc), are the most difficult. This information will alert teachers to the need to remind students to use more caution when working with longer sequences, or with letters that only consist of a body. This will enable the student to focus on 'tricky' spellings (such as 'coat', for example), in order to remember the sequence of the central letters. The teacher may then develop a cuing method to teach students to assist them to choose the correct sequence. Such cues may include breaking up the spelling words into shorter sequences when learning them as in ‘c’-‘oat’ or learning spelling as acronyms, for example “**c**an **O**llie **a**ctually **t**rip?” Thus students can make progress in learning when the students are made aware of their areas of difficulty with regards to spatial orientation and sequencing, and are supported in developing skills that assist in mastering the mechanics of mathematics, spelling and reading specific to their needs.

Three uni-dimensional and reliable scales created for Form Constancy of Letters and Numbers (FCLN), Figure Ground Letters in Words (FGLW) and Figure Ground Numbers in Calculations (FGNC) allow for inferences to be drawn that relate to student abilities to use various fonts (such as **Victorian Modern Cursive**, Ariel, and **Times New Roman**) and find reversed letters or numbers when embedded within the context of the work (such as: Never and 60 + 5 = 65). The lowest scoring students in Form Constancy Letters and Numbers displayed difficulty in identifying reversed letters (such as: b in d| D d b d d) but were more capable of identifying the reversed numbers (such as S in 2| 2 S 2 2 2) when they were presented in a variety of fonts (such as **Victorian Modern Cursive,** Arial and **Times New Roman**). This indicates that for students who are experiencing difficulty in the identification of various letters related to the font style, a smaller variation in font style of letters should be used initially to avoid confusion for these students and to empower them to learn at a faster pace.

Students can use the outcomes of the Figure Ground Numbers in Calculations to their advantage, by understanding the difficulty with ‘busy pages’ (these are pages where there is a lot of letters, numbers, words or sequences on a page written closely together and in a small font size such as font size 12) and may be taught to use a line guide or window exposure sheet where the page is covered except for the section or line of calculation on which they are currently working. This allows them to focus on the immediate problem and enables students to break up the numbers into smaller segments such as in the calculation: 23 – 3 = ?; the students can use the window sheet to cover each segment and study each segment separately drawing attention to the sign used in the calculation. Students with difficulty in Figure Ground Numbers in Calculations can also use the information to practise combinations with smaller numbers (below 10) until they are confident in the use of individual numbers so that they are able to use that information when working with larger numbers. This was supported by a study of number problems in linear equations with junior secondary students in Singapore (Devi, 2007). In this way, if students can easily identify bonds (number combinations adding up to ten) of ten, then they can add larger numbers by breaking them down into these bond groups for example: 71 + 18 = ? can be worked out by adding 8 + 1 and 7 + 1 then putting the two numbers together = 89. If students are made aware of various layouts used in mathematics, the students will be able to switch unfamiliar layouts to familiar layouts to promoting their learning, for example $\begin{array}{r}19\\+34\\\hline\end{array}$ can be converted to $19 + 34 = ?$

Identifying the types of letters and numbers that students found most difficult, as well as the contextual difficulties that students experienced, will endow students with insight into the type or style of learning the students are using. It would, thus, enable the student, with the assistance of the teacher or therapist, to develop strategies to assist the student in learning. Time can be used effectively to practise the skills that are problematic and avoid the student developing a general feeling of inability.

Implications for Therapists and Parents

The results and publication of this study will provide therapists and parents of students who have difficulty with letter and number recognition, access to guidelines regarding the development of understanding of letter and number directionality, context and sequencing for each specific student. This will mean that therapists and parents can have the same access as the teachers to information regarding the student's areas of difficulty and will better equip these therapists and parents to apply timely and precise interventions for the lowest scoring students in order to ensure that students progress at the same rate as their peers or the expectation according to the curriculum guidelines.

Identifying the types of letters and numbers that students found most difficult to discriminate in Visual Discrimination of Upper Case letters, Visual Discrimination of

Lower Case letters and Visual Discrimination of Numbers will enable therapists and parents to assist the students in developing their strategies to learn and remember letter and number discrimination and directionality. Examples include teaching students that all the letters with a ‘circle’ in the body of the letter begin with a ‘c’ which may then assist the students in developing the skill to avoid reversals where they may begin with the ‘stick’ and then add the ‘circle’, but become confused as to which side of the ‘stick’ the ‘circle’ should be placed. Beginning with the ‘c’ gives an additional clue that the ‘stick’ must be on the right as in ɒ a, b d and g ϱ. The contextual difficulties that students experienced in Spatial Orientation of Letters and Numbers, Letter and Number Sequencing, Form Constancy of Letters and Numbers, Figure Ground of Letters in Words and Figure Ground Numbers in Calculations will provide therapists and parents with insight into the type or style of lettering that an individual student is finding difficult, as well as the volume of work presented on a page. Thus therapists will be able to streamline each student’s therapeutic interventions with regards to letter and number recognition skills for the best possible outcomes by using an appropriate font, and distributing work on the page so that the students gain the most benefit from the learning situation. Less attention can be given to developing letters which students found easiest to discriminate such as the capital letters that are symmetrical around the vertical axis (as in T, Y, and H) and more attention to the letters that students found most difficult, such as the lower case letters that consist only of a body (such as a, c, s and o). Explanation and examples of all the scales will not be repeated here in order to avoid repetition of the implications for teachers which has similar implications for therapists and parents.

Implications for Future Research

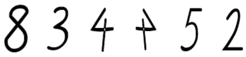
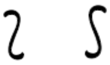
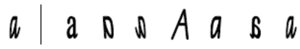
Further Rasch Measures

The Rasch Measurement Model was used to create uni-dimensional, linear and reliable measures so that valid inferences can be made from it. Rasch measurement, as used in the present study, should be used more in educational research in order to create reliable measures that are informative and valid in developing teaching strategies and insight into the learning methods of students. Furthermore, the scales developed in this study need to be retested using Rasch measurement after they have been re-arranged with more difficult as well as easier items added (see Table 11.1) to cover a larger range of student abilities. Refining these scales will result in a more stable and reliable measure of students' abilities to learn and manipulate letters and numbers in a variety of contexts.

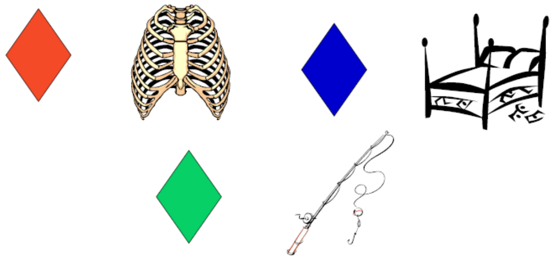
The findings of the current research have lead to further questions which may be addressed in future research projects. One of these future research questions may include creating improved items for each scale. Examples of other items for each scale are suggested in Table 11.1. A further question may relate the current scales to a different font, such as the font used in printed matter (Arial, or Times New Roman) or Ball and Stick fonts such as the Foundation Print (for example: J, P,b, d, r) rather than the Modern Victorian Cursive Font which was used in this research.

Table 11.1:

Examples of Suggested Items for Inclusion in Future Research.

SCALE	SUGGESTED ITEMS
Visual Discrimination of Upper Case Letters	
Visual Discrimination of Lower Case Letters	
Visual Discrimination of Numbers	
Spatial Orientation Letter and Number Pairs	Moving the pairs further apart with more space between the letter and number pairs may change the level of difficulty . Also, the arrangement of whether the correct or incorrect option is placed first in some instances may make the task more difficult, especially for students who randomly select all the first or all the second options.
Letter And Number Sequencing	Including longer sequences with a larger space between them will make the comparisons more difficult. Thus examples to include may be number sequences such as: , letter sequences such as: , and letter sequences where the letters consist of only a body as in: .
Form Constancy of Letters and Numbers	Reversed letters in all the given fonts may give a clearer indication of the students' ability such as: 
Figure Ground of Letters in Words	Using a smaller font and more advanced words such as alphabet (), astronaut (), and recycling ().
Figure Ground of Numbers in Calculations	Adding in calculations that involve numbers in the hundreds as well as a combination of signs, for example: 169 + 24 = 193 and 7 x 4 + 9 = 37

Further research may also focus on creating scales that assess other aspects of visual perception related to letters and numbers as used in reading, mathematics and spelling, for example visual closure (used in completing letters, numbers, words and calculations, for example: d, p, c_ow) and visual memory (for example the student is shown the word ‘red’ and is then asked to choose the correct picture from a sheet such as:



Mixed Methods

In the present study, a mixed-methods research approach was used so that the qualitative insights gained from focus group interviews complimented the scales created using the Rasch Measurement Model. The implications of mixed methods in future research will mean that researchers can capitalise on the strengths of qualitative and quantitative approaches to enhance information gathering from multiple sources to provide better understanding of how primary school students learn and how they find solutions for concepts that are difficult for them to grasp. One method of determining how students think is to use a ‘think aloud’ concept, where the student verbalises what they are thinking as they work through the scales. This concept will enable all the comments students made regarding the style, size, and shape of the letters and numbers to be recorded for accurate recall and analysis of their thoughts. This will lead to improved scales as the thought processes of the students can be incorporated in the scales, for example, multiple students asked whether the P 9 was a letter or a number, indicating that there is a need to change the configuration of the ‘9’s in this particular setting.

Qualitative research may further add to the quality of the Rasch measures as the reasons for students finding certain letters or numbers more difficult than others can be determined. The Rasch scales produce un-dimensional linear scales from the data, but they do not explain why the students responded to the data in this way. Questioning students and teachers about how students respond to certain letters and numbers when learning may enlighten the knowledge base on ways to adapt teaching methods to enable students to learn the difficult letters and numbers more effectively. Some questions eventuating from the Rasch measures are: (1) why did some letters fail to fit the model, (2) were the letters and numbers that did not discriminate well and therefore did not fit the model easily for the same number of students as found them difficult, or were the items poorly formatted, (3) how can additional items be formatted to ensure that the resulting scales are improved?

This study can be extended by using information from focus group interviews with students during social conversations about learning, writing and reading. In addition, focus groups using social production of knowledge (Kvale & Brinkmann, 2008) with teachers of young students may develop a different view of the processes that students use in learning to read, spell, write and compute numbers, which will strengthen the knowledge of student learning and lead to better scales using the Rasch Measurement Model. Future questions should focus on aspects such as: (1) perceived errors in font style, (2) perceived impression at first glance as to why a certain item or contents on a page would be more difficult or easier for students, (3) the difference in the appearance of certain letters (for example: b/b, a/a) and numbers (for example: 9/9) in different font types.

Teaching and Therapy

Further research into the effective approaches of guiding students in overcoming their difficulties in the areas of visual discrimination, spatial orientation, form constancy, sequencing and figure-ground numbers and letters can be performed to provide more information about how to help students. Examples of approaches are: (1) using computer programs to enhance learning; (2) small co-operative group teaching involving an occupational therapist assisting with the visual perceptual aspects of spatial directionality and phoneme-grapheme correspondence; (3) using educational games such as ‘sound/blend bingo’ where the students match cards for sound and shape; and (4) using classical music in the background while teaching (Riddoch & Waugh, 2003).

This research can be informed further by using magnetic brain resonance while students are completing the current scales and comparing the outcomes to magnetic brain resonance while students are for example reading (Klingberg et al., 2000) will indicate whether the scales tap into the same brain processing areas as when students are reading, writing or computing numbers. In addition, information from the Astronaut Invented Spelling Test (Nielson et al., 2009) may be a useful tool in demonstrating the relationship between sounds and visual discrimination of letters and words. These approaches need to be trialled in a variety of situations in order to assess what is most effective then the current, improved scales can be used to direct the application of the approaches to learning.

Longitudinal Studies

It would be useful to complete a longitudinal study, gathering data that follows the development of a number of students from the time they enter school at the Kindergarten level (4 years old) to when they begin secondary school (12 years old). Data collected in this study should include a series of continual standardised test data related to functional reading, spelling and mathematical levels (as in the Western Australian National Assessment Program for Literacy and Numeracy tests), that are compared to continual student test data of visual perceptual concepts (such as with the current scales) as well as continual student test data related to auditory perceptual concepts (phonology), such as The Astronaut Invented Spelling Test (Nielson, 2003). Continual student and teacher interview data as well as magnetic brain resonance data will further inform this longitudinal study When analysed, this data may determine what perceptual level of functioning is required to reach certain levels of reading, spelling and mathematical skill. As a result teachers and therapists will be able to focus attention and teaching on pre-requisite visual and auditory perceptual skills when a student presents with particular reading, spelling or mathematical difficulties.

Final Reflection

This research has lead to the development of eight linear, uni-dimensional scales that can be used to assess students' letter and number recognition. The research provided the opportunity to gain insight into the way in which students manipulate letters and numbers cognitively. An understanding was developed about students' use of meta-cognition and reasoning to assist their perception of letters and numbers. In addition, knowledge was gained into the easiest and most difficult letters and numbers for students to accurately discriminate and understand, and common characteristics of students with the lowest scores were identified. However, this research has not resulted in the reaching of a destination where concrete answers are found for difficulties associated with letter and number manipulation for young students. Instead, it has initiated a journey involving a search for methods to respond to the students' need for supplementary support in overcoming letter and number confusion regarding the discrimination, spatial orientation, sequencing, form constancy and figure ground aspects of letters and numbers. This journey must continue so that the students who are 'mils mor clewer than enniwun els' may indeed become 'miles more clever than anyone else'; and 'I ownli got two in the speling test' may become 'I achieved full marks on the spelling test'!

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Appendix 1

Jordan Left Right Reversal Test Summary

TEST TITLE	***Jordan Left Right Reversal Test* (JLRRT)**
AUTHOR	Jordan, Brian T
PUBLICATION DATE	1990
PURPOSE	• Descriptive – Used to identify the type of letter and number reversal tendencies in children • Predictive – used as part of the battery of tests to diagnose learning disabilities, screening instrument for early identification of possible neurological dysfunction • Evaluative - To measure letter and number reversals in the area of visual receptive functioning in children aged 5 – 12 years
AGE RANGE FOR TEST	5 to 12 years
WHO CAN ADMINISTER THE TEST	Not reported in test manual. Remediation can be carried out by elementary school teachers, learning disability specialists, or other professionals such as psychologists and medical specialists working in the field
TIME TO ADMINISTER	About 20 minutes
TIME TO SCORE	10 to 15 minutes
MATERIALS/EQUIPMENT REQUIRED	Pencil, response booklet, manual, sheet with large printed alphabet for pre-school 5 year olds.
METHOD OF ADMINISTRATION	Individual or group administration RESPONSE FORMAT- child is required to strike through or circle with a pencil letters/numbers/ words that are reversed
SCALE CONSTRUCTION / TEST STRUCTURE	• ITEM GENERATION – Level 1: panel of judges selected only letters and symbols that represented a clear-cut reversal. Level 2: no detail pertaining to the selection of words or construction of sentences • ITEM SELECTION – panel of experts in the field. • NUMBER OF ITEMS – Level 1 (5 to 12 years): 27 upper case letters, 27 lower case letters and 14 numbers in correct and reversed orientation. Level 2 (9 to 12 years): 98 words containing 39 errors and 20 sentences containing 13 reversed words. • NUMBER OF SUBSCALES – Total score only
STANDARDISATION	• SIZE –More than 3000 (as reported in manual) • GENDER – male/female ratio not reported • GEOGRAPHIC AREA – Not reported in test manual • EDUCATIONAL LEVEL – All socioeconomic levels incorporated • INTELLECTUAL LEVEL – Average intelligence (90+ IQ) • ETHNICITY – 10% non-white racial background included • SPECIAL NEEDS – Mentally retarded, emotionally disturbed and learning disabled children excluded from normative sample
SCORING	• STANDARD SCORES – Not available • PERCENTILES – at each age level and gender. Derived from distributions of raw error score and corresponding cumulative percentages for each 6-month age level. Normal limits indicated by percentiles above 50 percentile • SCALE SCORES – Not available

- AGE EQUIVALENTS – at each age level and gender. Developmental age developed by plotting mean raw scores at 6-month intervals against the midpoint of the chronological age.
- TWO-FACTOR ANALYSIS – age and sex significant factors at p<.01

RELIABILITY

- INTER-RATER: Not able to calculate as test items are answered by respondent themselves
- INTRA-RATER: Not able to calculate as test items are answered by respondent themselves
- TEST-RETEST – 99 children tested using 2-week interval. Reliability of .6 (5yo) to .94 (7, 10 & 11yo).
- TEST-RETEST INTERVAL – 2 weeks
- ERROR OF MEASUREMENT – not reported
- INTERNAL CONSISTENCY – not reported
- SPLIT-HALF/ALTERNATE FORM – not reported

VALIDITY

- FACE VALIDITY: Appears to assess the occurrence of reversals of letters, numbers, letters in words and whole words
- CONTENT VALIDITY – only used letters, whole words and numbers that were clear reversals when reproduced in left/right position
- CRITERION RELATED VALIDITY
    - CONCURRENT – using representative sample of children aged 6-12. T-test used to compare to the JLRRT with the Bender Gestalt Test (t = 24.53) and Wide Range Achievement Test (t = 59.91) at the .001 level of significance.
    - PREDICTIVE – Identified Reading Disabled children scored significantly higher than normal children. Sample size 220 children aged 6-12 years.
- CONSTRUCT VALIDITY
    - CONVERGENT – not reported
    - DIVERGENT – not reported
    - DISCRIMINANT – not reported
    - FACTOR ANALYSIS – not reported

CLINICAL UTILITY

A comparative study (Cotter et al., 1987) on 510 regular classroom and 126 learning handicapped children indicated poor agreement of JLRRT results to subjective evaluations of reversals by teachers – thus limited clinical utility

A study by this researcher indicated high level of utility in identifying reversal tendencies

SENSITIVITY

Not reported

KEY REFERENCE

- (Jordan, 1990)
- (Cotter et al., 1987)
- (Burns & Snow, 2006)

COST

AUS$90 as at 2006

SUPPLIER/PUBLISHER

Silvereye Educational publications Pty LTD, PO Box 715, Raymond Terrace, NSW 2324
Ph: 02 4987 3457

STRENGHTS

- Easy to administer with specific instructions for 5, 6-8 and 9-12 year olds
- A section on remediation of reversals for various age levels included in test manual
- Considers reversal tendencies in letters, numbers, words and whole word reversals

WEAKNESSES

- Inadequate validity data to support test as screening instrument or

	diagnostic battery for learning disabled • Minimal information concerning standardization sample. • Test-retest interval of one week makes effect of practice a consideration • Inflated reliability may be reported for older children as they tend to make fewer errors • Performance is strongly related to reading ability

Appendix 2

Reversal Frequency Test

TEST TITLE	***The Reversal Frequency Test*** **(RFT)**
AUTHOR	Gardner, R.A
PUBLICATION DATE	1978
PURPOSE	Descriptive - measurement of the frequency of letter and number reversals made by children
AGE RANGE FOR TEST	5.0 to 15.11 years or 14.11 years (discrepancy in manual)
WHO CAN ADMINISTER THE TEST	Not specified
TIME TO ADMINISTER	10 to 15 minutes
TIME TO SCORE	5 minutes
MATERIALS/EQUIPMENT REQUIRED	3 Examination response sheets, Manual and pencil
METHOD OF ADMINISTRATION	Individual administration or group administration RESPONSE FORMAT – Written response, reading of individual letters
SCALE CONSTRUCTION / TEST STRUCTURE	• ITEM GENERATION/ SELECTION – only numbers and letters which could be written in mirror image were used • NUMBER OF ITEMS – 24 in subtest 1, 23 pairs and 46 single letters and numbers in subtest 2, and 20 items with one example in subtest 3. • NUMBER OF SUBSCALES – There are three subscales: Execution (writing), Recognition (recognition) and Matching (differentiation /discrimination)
STANDARDISATION	• SIZE – 500. Normative data collected on 254. • GENDER – 249 girls and 251 boys (115 girls and 139 boys for normative data collection) • GEOGRAPHIC AREA – Bergin County, New Jersey (a suburb of New York City) • EDUCATIONAL LEVEL – normal range on national tests of academic achievement (20^{th} – 80^{th} percentile) • INTELLECTUAL LEVEL - Average range of intelligence (90-110 IQ) • ETHNICITY: Not reported in test manual • SPECIAL NEEDS – no grade repeats, special tutoring or previous placement in class for learning disabled were included
SCORING	• STANDARD SCORES – for children aged 5.0 – 14.11 • PERCENTILES – presented in the manual as the number of errors (deciles); presented as percentiles, but actually are not • MEANS - Given • SCALE SCORES – not reported in test manual • AGE COMPARRISONS – not reported in test manual
RELIABILITY	• INTER-RATER – not reported in test manual • INTRA-RATER – not reported in test manual • TEST-RETEST – not reported in test manual • TEST-RETEST INTERVAL – not reported in test manual • ERROR OF MEASUREMENT – not reported in test manual • INTERNAL CONSISTENCY – not reported in test manual • SPLIT-HALF/ALTERNATE FORM – not reported in test manual
VALIDITY	• FACE VALIDITY – Item selection not developmentally correct as 8 year olds made more errors than 7 year olds on Matching subtest

	and 11 year olds made more errors than 8- 9- and 10 year olds on the Execution subtest
	• CONTENT VALIDITY – not reported in test manual
	• CRITERION RELATED VALIDITY – not reported in test manual
	  o CONCURRENT
	  o PREDICTIVE
	• CONSTRUCT VALIDITY – not reported in test manual
	  o CONVERGENT
	  o DIVERGENT
	  o DISCRIMINANT
	  o FACTOR ANALYSIS

CLINICAL UTILITY	External reviewer's comments – "It is difficult to determine if the RTF does what it purports to do…the RTF may prove to be an excellent screening instrument, yet much technical work is needed" (Gresham & Mealor, 2006). Until the reliability and validity is established, the value of the RTF will be limited.
SENSITIVITY	Not reported in test manual
KEY REFERENCE	• (R. A. Gardner, 1978) • JOURNAL ARTICLES • (Gresham & Mealor, 2006)
COST	USD$60
SUPPLIER/PUBLISHER	Optometric Extension Program Foundation INC, 1921 E. Carnegie Avenue, Suite 3L, Santa Ana, CA 92705-5510
STRENGHTS	• Easy to administer
WEAKNESSES	• Sample is unrepresentative • No comparison of "normal" and MBD children • Poorly written manual • No clear rationale for the test • Vague and ambiguous • No reliability and validity data • Inadequate description of standardization, administration and scoring • Author is the only reference • Comparison of Minimal Brain Dysfunction (no details) and normal children based on unknown "statistical analysis" • No consistent pattern of differences between normal children and MBD children at various ages could be revealed. • The test does not appear to measure what it says it does, or the sample is unrepresentative or both

Appendix 3

Test of Pictures/Forms/Letters/Numbers/Spatial Orientation & Sequencing Skills

TEST TITLE	***Test of Pictures/Forms/Letters/Numbers/Spatial Orientation & Sequencing Skills*** **(TPFLNSOSS)**
AUTHOR	Gardner, M.F
PUBLICATION DATE	1991
PURPOSE	• Evaluative – evaluate reversal tendencies in children • Descriptive - Identification and diagnosis of children who confuse the orientation and sequence of language symbols
AGE RANGE FOR TEST	5 years to 10 years 11 months
WHO CAN ADMINISTER THE TEST	No training required – should be administered by professionals with experience in test administration
TIME TO ADMINISTER	15 minutes for younger children, 10 minutes for older children
TIME TO SCORE	10 minutes
MATERIALS/EQUIPMENT REQUIRED	No visible aids should be available. Test booklet and pencil
METHOD OF ADMINISTRATION	Individual or groups RESPONSE FORMAT: multiple-choice.
SCALE CONSTRUCTION / TEST STRUCTURE	• ITEM GENERATION/ ITEM SELECTION – items selected as appropriate and applicable for children aged 5 years to 10 years in all geographical areas of America. All items showing significant association were eliminated, items with low-biserial correlation to total score were retained • NUMBER OF ITEMS: 148 items • NUMBER OF SUBSCALES: 7 subtests: o Spatial Relationships- pictures (10 items), o Spatial Relationships – Forms (14 items), o Reversed Letters and Number of Two Letters (13 items), o Reversed Letter(s) in Words (27 items), o Reversed Letters from Non-Reversed Numbers (68 items), o Letter Sequencing (16 items).
STANDARDISATION	• SIZE: 714 children • GENDER: Breakdown of number of boys versus number of girls is not reported in the test manual. No significant variance between male and female • GEOGRAPHIC AREA – San Francisco Bay Area – Private, Public and Parochial Schools • EDUCATIONAL LEVEL - • INTELLECTUAL LEVEL • ETHNICITY – No significant variance shown on chi-square test • SPECIAL NEEDS – Children with limited use of English and Known learning problems were excluded
SCORING	• STANDARD SCORES – for each two-month age group for ages5 & 6 years, for each 6 month interval for ages 7 & 8 years. Mean of 100 and standard deviation of 15 • PERCENTILES – for each age group • SCALE SCORES – for each age group • AGE EQUIVALENTS • Cumulative frequency of distribution of raw scores for each age level and smooth curve fitted

RELIABILITY	• INTER-RATER: Not reported due to response format of test • INTRA-RATER: Not reported due to response format of test • TEST-RETEST: Not reported in the manual • ERROR OF MEASUREMENT – Ranged from 3.26 for 5 year olds to 5.60 for 8 year olds. Decline in SEM for older children due to ceiling effect in test. • INTERNAL CONSISTENCY– kr-20 formula – reliability for sum of scaled scores ranged from 0.85 to 0.95 across the age range • SPLIT-HALF/ALTERNATE FORM: Not available
VALIDITY	• FACE VALIDITY: Appears to measure perception of pictures, forms, letters, numbers, spatial orientation and sequencing skills • CONTENT VALIDITY – Subtest inter-correlations ranged from 0.44 to 0.87. No gender difference evident in item selection. Bias according to language and culture • CRITERION RELATED VALIDITY o CONCURRENT– Moderate correlation to Jordan. Correlation to *Wechsler Intelligence Scale for Children-Revised*, *Test of Visual Perceptual Skills*, reading and spelling tests, *Visual-Motor Integration Test*, *Test of Visual Motor Skills* were higher. Only conducted for 6year olds. o PREDICTIVE • CONSTRUCT VALIDITY o CONVERGENT: Not reported in manual o DIVERGENT: Not reported in manual o DISCRIMINANT – Learning Disabled children scored lower than the norming group. No detail of how LD was defined. o FACTOR ANALYSIS: Not reported in manual
CLINICAL UTILITY	Useful in analysing visual perceptual ability of younger children up to 7 or 8 years of age to identify direction in pictures, forms, letters, numbers and sequences.
SENSITIVITY	Not reported in the test manual
KEY REFERENCE	• (M. F. Gardner, 1991)
COST	USD$52.00 Complete Kit (2006)
SUPPLIER/PUBLISHER	Psychological and Educational publications Inc Silvereye Educational publications PTY LTD, PO Box 715, Raymond Terrace, NSW 2324. 02 49873457
STRENGHTS	• Ease of administration – older children complete test in one session • Quick and easy scoring • No verbal response required • No reading/language comprehension is required • Combines visual perceptual concepts with classroom related tasks involving letters and numbers
WEAKNESSES	• Younger children require test to be divided over sessions. • Some psychometric evidence was taken from the earlier version of the *Test of Visual-Perceptual Skill (non-motor)* • Reaches a ceiling early on, as some subscales do not have enough difficult items for 7, 8 and 9 year olds • Letters/numbers from the back of the page show through the page in a reversed manner.

Appendix 4

From:	Research Ethics
Sent:	Thursday, 9 October 2008 5:10 PM
To:	Janet RICHMOND
Cc:	Russell WAUGH; Deslea KONZA; Sarah KEARN; Karen LECKIE
Subject:	3054 RICHMOND
Attachments:	HREC Ethics Report Form.doc

Dear Janet

3054 RICHMOND
The development and validation of a visual perceptual letter and number reversal recognition test in school-aged children

Student Number: 10133044

The ECU Human Research Ethics Committee (HREC) has reviewed your application and has granted ethics approval for your research project. In granting approval, the HREC has determined that the research project meets the requirements of the *National Statement on Ethical Conduct in Human Research*.

The approval period is from 9 October 2008 to 31 December 2011.

The Graduate Research School has been informed and they will issue formal notification of approval. Please note that the submission and approval of your research proposal is a separate process to obtaining ethics approval and that no recruitment of participants and/or data collection can commence until formal notification of both ethics approval and approval of your research proposal has been received.

The *National Statement* indicates that the HREC is required to retain on file a copy of each approved research project. Please forward one signed paper copy of your finalised application, including all attachments, to the ethics office (if this has not already been done).

Please note the following conditions of approval:
The HREC has a requirement that all approved projects are subject to monitoring conditions. This includes completion of an annual report (for projects longer than one year) and completion of a final report at the completion of the project. An outline of the monitoring conditions and an ethics report form are attached for your information. You will also be notified when a report is due.

Please feel free to contact me if you require any further information.

Regards
Kim

Kim Gifkins
Research Ethics Officer
Edith Cowan University
270 Joondalup Drive
JOONDALUP WA 6027
Phone: (08) 6304 2170
Fax: (08) 6304 2661
Email: research.ethics@ecu.edu.au

Appendix 5

Janet Richmond
Edith Cowan University
Faculty of Computing, Health and Science
100 Joondalup Drive
Joondalup WA 6027

The Principal

Dear Sir/Madam,

RE: Conducting a non-intrusive research project at ____________________(name of school)

I am currently employed at Edith Cowan University as a lecturer in occupational therapy, and am studying through Edith Cowan University towards a PhD. My research project involves the development and validation of an assessment of visual perceptual letter and number reversal recognition. The aim of this research is to establish norms of letter and number reversal tendencies of primary school children with the view to early identification and intervention using this tool in the future.

I have requested Department of Education and Training approval to approach schools to allow me to access some of the pupils in order to carry out this research. In return for the privilege of access to your school and the pupils to conduct this research, I would like to offer an in-service training session to your staff and/or the parents of your school relating to the influence of visual perception on learning and what we can do to assist children with visual perceptual difficulties (or on another occupational therapy related topic). Participation in the research is completely voluntary. The commitment from each child will be approximately 30 minutes where they identify reversed letters and numbers from a given array on a page. These letters and numbers are presented in a number of contexts eg, individually, in words or calculations and in sentences.

All information will be kept confidential. No names will appear on the test forms and only the child's exact age will be recorded on the test forms. For this reason there will be no way of identifying who completed each test form, however the demographics from the form the parents complete will appear on the test form for categorisation purposes. Storage of the data collected will adhere to Monash University and Edith Cowan University regulations and will be kept on University premises in a locked cupboard/filing cabinet in a locked office for 5 years. The information entered onto the computer will be de-identified and will be password protected. A report of the study may be submitted for publication, but individual participants and schools will not be identifiable in such a report.

If you are in agreement with the research being conducted at __________(name of school), I will negotiate with you regarding appropriate times to attend the school for the research and training session. It may be a number of days in one week or one day a week for a number of weeks, depending on what suits your school and the number of children who agree to participate in the project. I do not foresee that the entire time spent at your school will be more than four to six days. I would envisage assessing four to six children simultaneously. It would be beneficial to the project if there was a room separate from the classroom in which we could work, however this may be a storeroom at the back of the classroom or an office or a corner of the school hall. (It may be possible to complete the assessment at the back of a classroom, but this may potentially pose to be a negative influence on the outcome of the study and may be a greater distraction to the other class members and is therefore not desirable.) All resources other than a space to work and a desk and chair will be supplied by the researcher. Other than collecting the forms and being disturbed when children are collected from the class, the teachers will not be involved unless they have any specific queries.

I look forward to working in your school and sharing skills with your staff. Should you have any further questions, please contact me on 08- 6304 2351 or on j.richmond@ecu.edu.au.

Thank you for your consideration to this request.
Janet Richmond

Reply Agreement for Research Project

I have read and understood the Explanatory statement. I understand that participation in this research is voluntary and will not be paid for. I agree to ____________________ (name of school) participating in this research project with involvement of any one child limited to approximately 30 minutes during the school day at a time agreed to by the school and Janet Richmond.

Name of Principal ____

Signature ____

Date ____

Contact number to arrange a meeting time:___________________________

Appendix 6

January 2008

This information sheet is for you to keep.

The development and validation of a visual perceptual letter / number reversal recognition test in school-aged children.

Research Project for children ages 5-12 years

My name is Janet Richmond and I am conducting a research project with Dr Russel Waugh and A/Professor Deslea Konza towards a PhD in Occupational Therapy at Edith Cowan University. I am completing a study looking at the way that children perceive and understand letters and numbers presented to them on a piece of paper. I am developing a test for children aged 5 to 12 years old. Part of the process of developing this test requires that I collect performance scores of children on the test of letter and number recognition. Therefore, I will be collecting data on academic performance of children in primary schools in and around Perth. Permission was obtained from the Western Australian Department of Education and Training to complete this study. The principal at your child's school has agreed to allow me to collect this information from children in this school provided their parents are in agreement.

The purpose of this research is to establish the normal prevalence of reversing letters, numbers or words amongst children in primary school. This will be established by a multiple choice format test. I will then use this information to establish what level of letter and number reversals are acceptable for children at each grade level. There are no pass or fail points on the test, just observation of how the children perceive the letters and numbers.

Possible benefit of this research is that it will establish a baseline which will guide teachers and therapists in the construction of programmes that will help children who have difficulty with directions of letters and numbers. Your child's participation in this study will contribute to this bank of knowledge that will help other less fortunate children.

What does the research involve? I am looking for preschool to grade 6 children who will spend approximately 30 minutes completing a test. The test consists of pages of printed letters, numbers and words and your child will be asked to identify which ones are facing the wrong way. I will need to know the nationality, gender, grade and date of birth of each child in order to establish whether the information is a true representative of the general population. I will not allow the child's name to be identified with any work once they have completed the test. I may ask the child to comment on their impression of the test after completion of the exercise and will write down what they say without writing down the child's name.

How much time will the research take? The entire test should take less than 30 minutes and will be performed on the school premises.

No payment will be offered to children or children's parents for their involvement in the research.

The child should not feel uncomfortable at any time during the activity, but should they for some reason no longer want to participate, then they are free to say so. At that point the activity will be stopped and no further information will be gathered from your child. As a number of children from each class will be participating, the child will not feel singled out.

Can I withdraw from the research? Enrolling your child in the study is voluntary and you are under no obligation to consent for your child to participate. If you do consent for your child to participate, you may withdraw your consent at any time prior to *final completion of all activities*. Once the activities are complete and submitted to the computer programme, there will be no identifying information to withdraw them from the group results.

All information will be kept confidential. No names will appear on the test forms and only the child's exact age will be recorded on the test forms. For this reason there will be no way of identifying who completed each test form.

Storage of the data collected will adhere to Edith Cowan University regulations and will be kept on University premises in a locked cupboard/filing cabinet in a locked office for 5 years. The information entered onto the computer will be de-identified and will be password protected. A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report.

If you would like to receive a copy of the summary of the study results, please contact Janet Richmond on j.richmond@ecu.edu.au. The study results will also be posted on the Edith Cowan University Occupational Therapy Program website if you wish to download a copy of them. It is anticipated that the study results will be available in 2010.

If you would like to contact the researchers **about any aspect of this study, please contact the Chief Investigator:**	**If you have a** complaint **concerning the manner in which this research** <insert your project number here, i.e. 2006/011> **is being conducted, please contact:**
A/Prof Deslea Konza Senior Lecturer Faculty of Education and Arts, Edith Cowan University - Joondalup Campus, 100 Joondalup Drive, Joondalup WA 6065, Australia Phone: +608 6304 5797 Email: d.konza@ecu.edu.au	**Human Ethics Officer ECU Human Research Ethics Committee Building 1, Block 'B', Level 3, Room 333, Joondalup Campus Edith Cowan University WA 6027 Tel: (+61 8) 6304 2170 Fax: (+61 8) 6304 2661 Email: research.ethics@ecu.edu.au**

Thank you.

Janet Richmond

Appendix 7

The development and validation of a visual perceptual letter / number reversal recognition test in school-aged children.

Parent Consent Form and Demographic Questionnaire

A research project conducted by Edith Cowan University

Subject Identification Number
(Research use only)

I have read and understood the Explanatory statement. I understand that participation in this research is voluntary and will not be paid for. I agree to my child participating in this research project for a maximum of 30 minutes during the school day at a time agreed to by the class teacher.

Name of Child

Signature of Child

Name of Parent(s)/Care-giver(s)

Signature of Parent(s)

Name of Witness

Signature of Witness

Date - - (dd-mm-yyyy)

The following statement will be read aloud to each paediatric subject participating in the study in order to obtain their oral consent:

"You don't have to answer the questions if you don't want to. You can stop at any time if you want or ask to take a short break. You can ask any questions that you have at any time too. Do you agree to look at some letters, numbers and words?"

I have explained the nature of the study to the child. I am satisfied that they have understood it.

Name

Signature of Child

Date - - (dd-mm-yyyy)

Demographics

Gender of Subject:

Male Female

Date of Birth

- - (dd-mm-yyyy)

Age

years months

Grade Level In School

PP 1 2 3 4 5 6

Type of School Attending

Public Private

Catholic Other

Is English the primary language spoken at home?

Yes No

Mother's Name

Daytime Phone Number

Father's Name

Daytime Phone Number

Name, Address & Phone Number of Family Physician

(The demographic data will be kept in a separate file to ensure confidentiality.)

Screening questionnaire

1. Has your child ever repeated a year of school?

☐ Yes ☐ No

2. Has your child ever received special education/resource assistance at school?

☐ Yes ☐ No

3. Has your child ever received any private tutoring or teacher assistance for learning problems or to help with school work?

☐ Yes ☐ No

4. Has your child ever been seen by a professional
(e.g., speech/language pathologist, occupational therapist, physiotherapist, social worker, psychologist) for any learning difficulties or to assist with educational problems?

☐ Yes ☐ No

5. Has your child ever been diagnosed / labelled as having any type of learning disability?

☐ Yes ☐ No

6. Has your child ever had an Individual Program Review Conference (IPRC) at school?

☐ Yes ☐ No

** Scores from any child scoring "yes" on any of items 1-6 inclusive will be used to calculate the discriminatory validity of the study.

Thank you for your participation.

Appendix 8

Department of Education and Training
Government of Western Australia

Your ref:
Our ref: D07/14562
Enquiries:

Ms Janet Richmond
Discipline of Occupational Therapy
Faculty of Computing, Health and Science
Edith Cowan University
100 Joondalup Drive
JOONDALUP WA 6027

Dear Ms Richmond

Thank you for your completed application received 24 October 2007 to conduct research on Department of Education and Training sites.

The focus and outcomes of your research project titled, *Visual Perceptual Reversal Test,* are of interest to the Department, and I give permission for you to approach site managers to invite their participation. However, it is a condition of approval that the results of this study are forwarded to the Department upon conclusion.

Consistent with Department policy, participation in your research project will be the decision of the particular schools invited to participate, the children in those schools and their parents.

Responsibility for quality control of ethics and methodology of the proposed research resides with the institution supervising the research. The Department notes a copy of a letter confirming that you have received ethical approval of your research protocol from the Monash University Human Research Ethics Committee.

Any changes to the proposed methodology will need to be submitted for Department approval prior to implementation.

Please contact Mr Sean Fitzpatrick, A/Senior Policy Analyst on (08) 9264 4068 or researchandpolicy@det.wa.edu.au if you have further enquiries.

Very best wishes for the successful completion of your project.

Yours sincerely

NORMA JEFFERY
EXECUTIVE DIRECTOR
POLICY, PLANNING AND ACCOUNTABILITY

7 November 2007

151 Royal Street, East Perth, Western Australia 6004

Appendix 9

DIRECTOR OF CATHOLIC EDUCATION

Catholic Education Office of Western Australia

21 September 2007

Janet Richmond
Department of Occupational Therapy
Faculty of Computing, Health and Science
Edith Cowan University
Joondalup Campus
100 Joondalup Drive
JOONDALUP WA 6027

Dear Ms Richmond

RE: THE DEVELOPMENT AND INITIAL VALIDATION OF A TEST OF VISUAL PERCEPTUAL LETTER/NUMBER REVERSAL RECOGNITION SKILLS FOR SCHOOL-AGED CHILDREN

I am writing with regard to your research proposal to design an instrument within a combined visual perception and occupational framework that is psychometrically sound. The test is developed for children aged 5 to 12 years old and data will be collected on the academic performance of children in primary schools in and around Perth. I note that the possible benefit of this research is that it will establish a baseline which will guide teachers and therapists in the construction of programs that will help children who have difficulty with directions of letters and numbers. I am pleased to give in principle support for your proposed study. However it is the decision of the principal with regard to each school's participation in the research project.

I give in principle support for the research. However, consistent with CEOWA policy, participation in your research project will be the decision of the individual principal and staff members with regard to their participation in the research project. The focus and outcomes of your research project are of interest to the Catholic Education Office, WA. It is a condition of approval that the research findings this study is forwarded to the Catholic Education Office of WA.

The contact person at the Catholic Education Office of WA is Karen Marais at marais.karen@cathednet.wa.edu.au or (08) 6380 5362.

I wish you all the best with your research.

Yours sincerely

Ron Dullard

50 Ruislip Street, Leederville WA 6007 • PO Box 198, Leederville WA 6903 • Telephone (08) 6380 5210 • Fax (08) 9212 9203
Email: dullard.ron@cathednet.wa.edu.au • Website: www.ceo.wa.edu.au

Appendix 10

VISUAL PERCEPTUAL LETTER AND NUMBER REVERSAL RECOGNITION TEST

Child's Name: ______________________ Gender: M / F Grade: ____

School: __________________________ Type: Public / Catholic / Private / Other

Examiner: __________________________

Year Month Day — Primary home language: English / Other

Test Date: ____/____/____

Date of Birth: ____/____/____

Test Age: ____/____/____

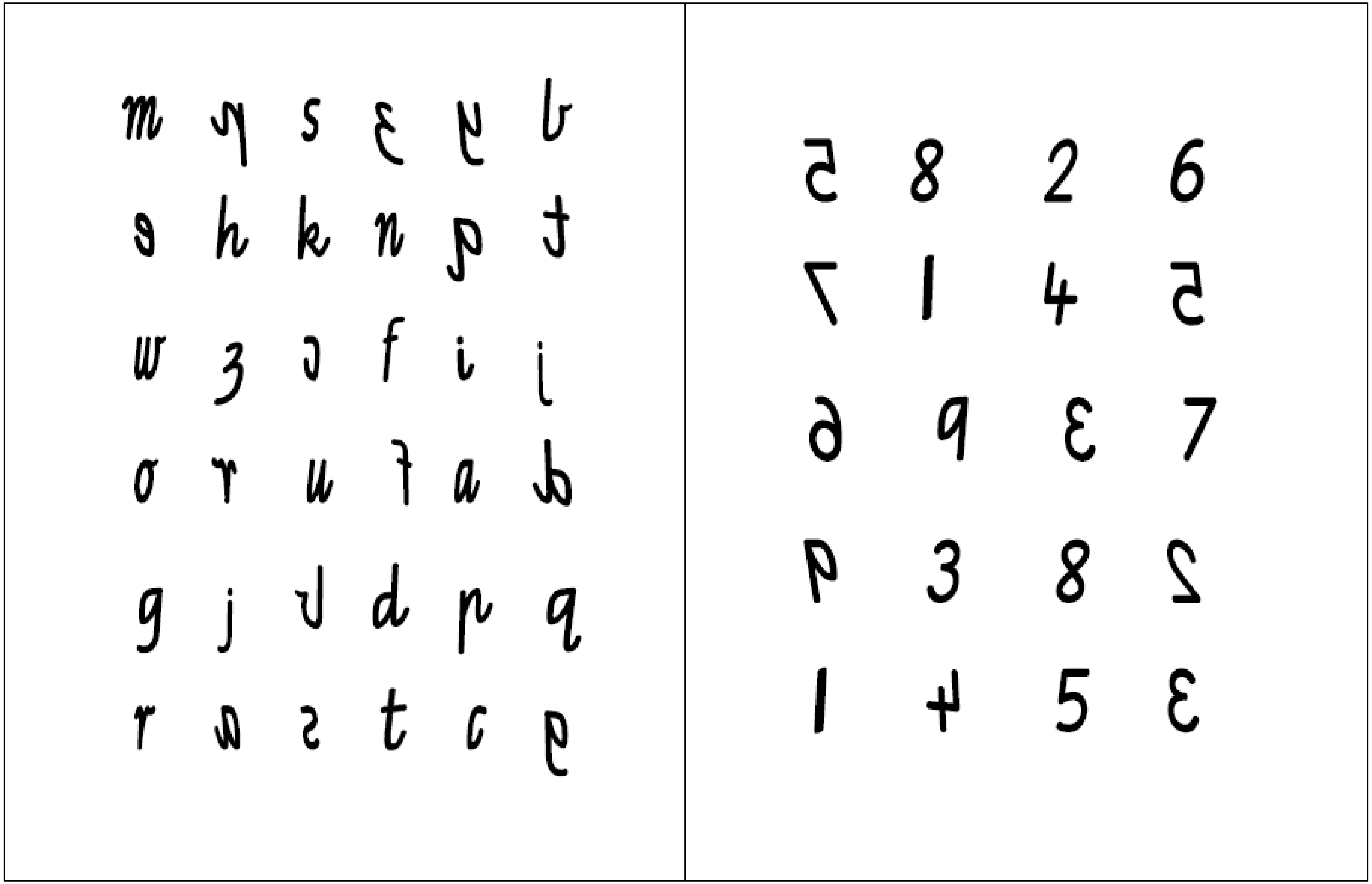
TEST RESULTS:

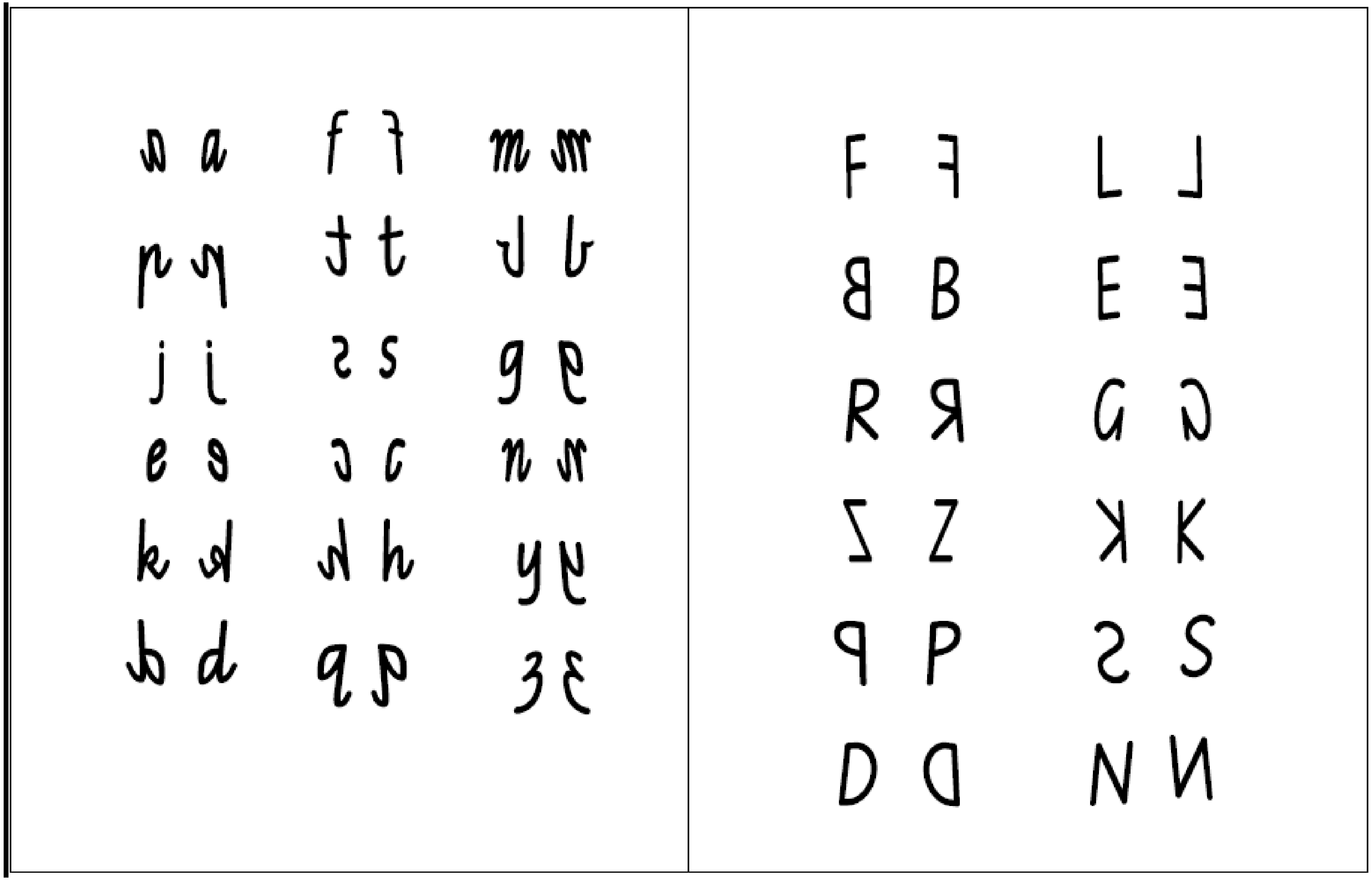
Subscales	Raw Score	Scaled score	Standard score	Percentile rank	Stanine
Visual Discrimination Of Upper Case Letters					
Visual Discrimination Of Lower Case Letters					
Visual Discrimination Of Numbers					
Lower Case Letter Pairs					
Upper Case Letter Pairs					
Number Pairs					
Words 4-6 years					
Words 5-7 years					
Words 6-8 years					
Words 7-9 years					
Words 8-11 years					
Numbers in context 1					
Numbers in context 2					
Numbers in context 3					
Numbers in context 4					
Letter and Number Matching					
Form Constancy of Letters					
Form Constancy of Numbers					
Number Sequences					
Letter Sequences					
Total					

Reason for referral: ______________________________________

Observations / Behaviour: ______________________________________

Janet Richmond 2007





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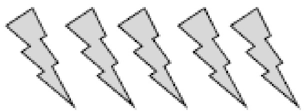


4 4 5 5

4 + 1 = 5

3 − 2 = 1

2 + 2 = 4

5 + 2 = 7

9 + 4 = 13

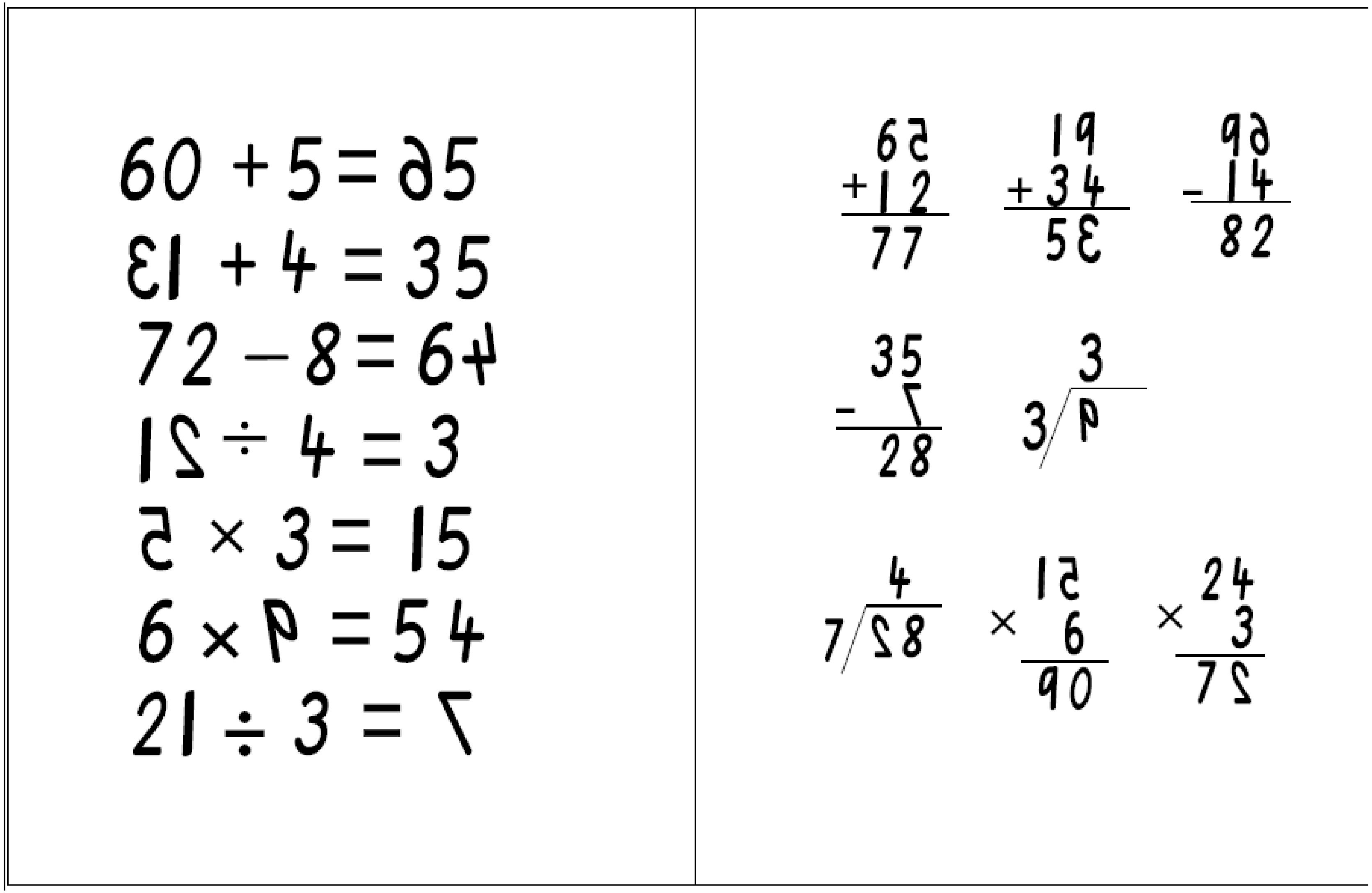
9 − 5 = 4

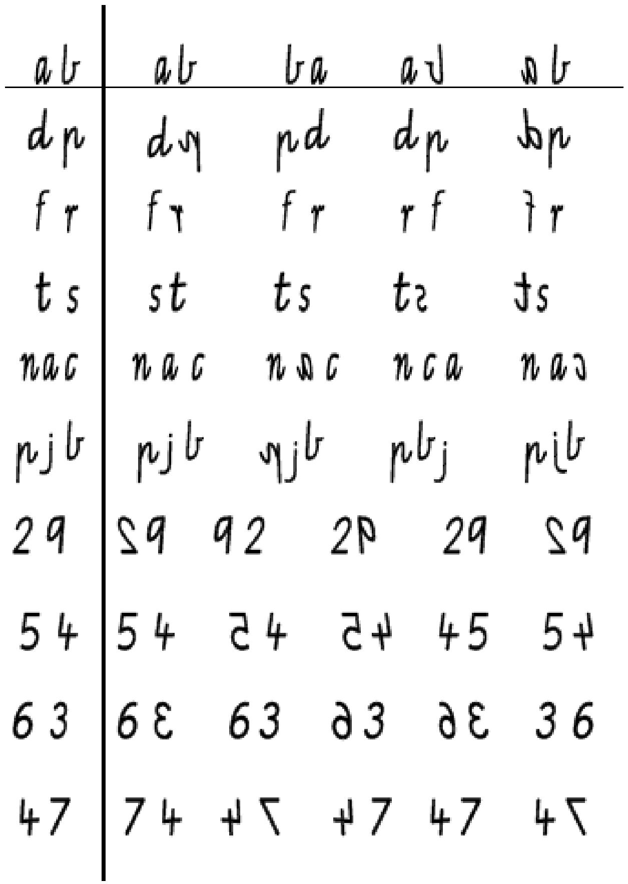
4 + 23 = 27

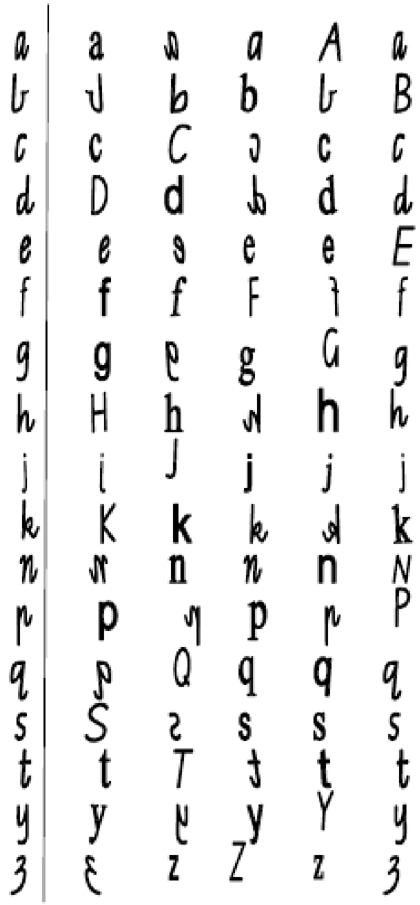
7 + 9 = 16

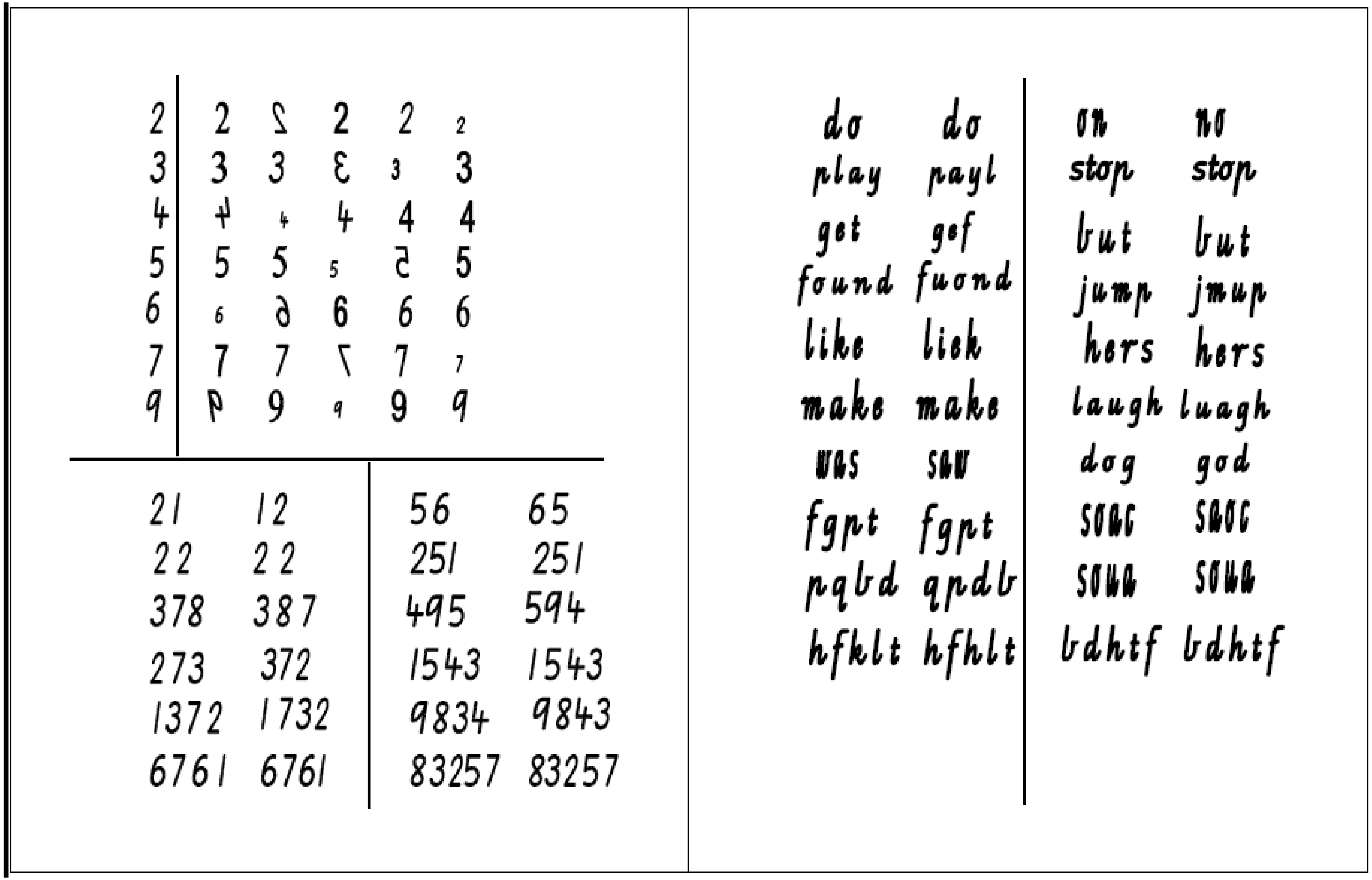
12 − 4 = 8

6 − 5 = 1









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get gef
found fuond
like lick
make make
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on no
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but but
jump jmup
hers hers
laugh luagh
dog god
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