An investigation of the convergent validity of the Movement Assessment Battery for Children-2 and the McCarron Assessment of Neuromuscular Development within an ecologically valid environment

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ABSTRACT
The convergent validity of the Movement Assessment Battery for Children-2 (MABC-2) and the McCarron Assessment of Neuromuscular Development (MAND) in an ecologically valid environment
Laura Cronin

Purpose: To investigate reliability and validity of the MABC-2 and the MAND in 7-9 year old children in mainstream schools.

Relevance: Poor motor skill development is a growing problem with children as physical, emotional and social co-morbidities can occur simultaneously or sequentially (Kaplan et al. 1998, Chen et al. 2009, Missiuna et al. 2007). As early detection is vital, ecologically valid, psychometrically robust assessments should be implemented within the child’s natural environment.

Participants: 114 7-9 year old children participated in the validation study. 20 children aged 7-9 years participated in the reliability study.

Method: Reliability Study: Children were assessed on two occasions, two weeks apart within their normal school environment. On the first occasion each child was scored by two raters (inter-rater reliability) and on the second occasion the child was re-assessed by the first rater (intra-rater reliability). Validation study: Counterbalanced administration of the MABC-2 and the MAND to children within their normal school environment.

Analysis: Intraclass correlations and limits of agreement were utilised to determine the reliability of the MABC-2. Correlations and case agreement were used to determine the validity of the MAND and the MABC-2. Performance of motor impaired children was compared to normally developing peers to determine which aspects of each test were good at discriminating between groups.

Results: MABC-2 has excellent inter- and moderate intra-rater reliability within this population. The MABC-2 and MAND have a large positive relationship; however there is a lot of independence between both tests. The case agreement between both tests in identifying children with motor impairments was poor (12.5%). Manual Dexterity was good at discriminating normally developing children from motor impaired children.

Conclusions: A lot of independence and poor case agreement exists between both assessments. Some aspects of the assessments are stronger than others at differentiating motor impaired children from their typically developing peers.

Implications: It is vital that motor assessments can be implemented within the child’s natural environment. Both of these assessments can be effectively implemented in groups within a school setting and can be very useful in identifying children with poor motor development; however the poor agreement between assessments highlights the necessity for a gold standard assessment which can be used as a criterion measure.
Author’s Declaration:

I hereby declare that the work contained in this thesis is entirely my own, and was completed without collaboration or assistance from others, apart from the guidance of my supervisors, Dr Amanda Connell and Dr Ciaran MacDonncha of the Department of Physical Education and Sports Sciences. I hereby give permission for this thesis to be lent or copied on request, with the consent of the librarian, and with due acknowledgement of the author.

Signed: ______________________________

Date: ______________________________
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Also, to Kieran and my friends at home in Cork, for always being a ready distraction at the weekends and who have always been there for me through thick and thin;

_The greatest sweetener of human life is friendship. To raise this to the highest pitch of enjoyment, is a secret which but few discover._

Joseph Addison

Most importantly to my parents and family, I owe everything I have achieved thus far to your endless love, support and guidance. Especially my Mom you always encouraged me to be who I am and do what I can do to the best of my ability;

_“Do not wish to be anything but what you are, and try to be that perfectly”_  
St. Francis De Sales

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# Table of Contents

Abstract.......................................................................................................................... I
Authors Declaration........................................................................................................ II
Acknowledgements.......................................................................................................... III
Table of Contents........................................................................................................ VII
List of Figures................................................................................................................ VIII
List of Tables................................................................................................................ IX
List of Appendices.......................................................................................................... XI
List of Abbreviations...................................................................................................... XII

Chapter 1 Introduction: ................................................................................................... 1
   1.1 Introduction to Motor Development in Children: .................................................. 1
   1.2 Statement of the problem ...................................................................................... 3
   1.3 Justification of study ............................................................................................ 4
   1.4 Thesis Objectives: ................................................................................................. 6

Chapter 2: A literature review of Developmental Coordination Disorder in children and the importance of accurate screening assessments within mainstream schools enabling diagnosis. ................................................................................................................................. 7
   2.1 DCD ....................................................................................................................... 7
       2.1.1 Co-morbidities: .............................................................................................. 10
       2.1.2 Diagnosis: .................................................................................................... 12
       2.1.3 Early intervention: ...................................................................................... 14
       2.1.4 Link DCD to School environment: ................................................................. 17
   2.2 Ecological Validity: ............................................................................................... 19
   2.3 Assessments of Motor Competence of Children: .................................................. 22
       2.3.1 Theoretical basis of types of assessments used: ............................................. 22
       2.3.2 Investigation of current assessments used within a classroom setting and psychometric properties of these assessments: ................................................................. 24
2.3.3 Justification for selection of assessments .................................................................33

2.3.4 Comparison of structure and content of the MABC-2 and the MAND ....................35

Chapter 3: The inter- and intra-rater reliability of the MABC-2 when administered in an
ecologically valid environment ..................................................................................37

3.1 Introduction: ................................................................................................................37

3.1.1 Types of reliability: ...............................................................................................40

3.1.2 Previous Reliability studies of the MABC test: ..................................................41

3.1.3 Reliability of the MABC-2 test: ...........................................................................47

3.2 Aims/ Objectives: ......................................................................................................50

3.2.1 Aim: ......................................................................................................................50

3.2.2 Objectives: ..........................................................................................................50

3.2.3 Hypothesis: .........................................................................................................50

3.3 Methodology: ............................................................................................................50

3.3.1 Study Design: ......................................................................................................50

3.3.2 Ethical Approval: ................................................................................................51

3.3.3 Participants: .........................................................................................................51

3.3.4 Outcome Measure: ..............................................................................................53

3.3.5 Procedure: ..........................................................................................................54

3.3.6 Data Analysis: .....................................................................................................55

3.4 Results: .......................................................................................................................58

3.4.1 Inter-rater reliability ............................................................................................58

3.4.2 Intra-rater Reliability .........................................................................................64

3.5 Discussion: ................................................................................................................70

3.5.1 Limitations ..........................................................................................................74

3.6 Conclusion: ...............................................................................................................75

Chapter 4: The convergent validity of the MABC-2 and the MAND in an ecologically valid
environment ..............................................................................................................76

4.1 Introduction ..............................................................................................................76

\[\text{V}\]
Chapter 5: Discussion .............................................................................................................. 122

5.1 Introduction ...................................................................................................................... 122

5.2 Literature Review (Chapter 2) ....................................................................................... 123

5.3 Reliability Study (Chapter 3) ......................................................................................... 124

5.4 Validation Study (Chapter 4) ......................................................................................... 127

5.5 Clinical Implications ........................................................................................................ 129

5.6 Recommendations ......................................................................................................... 130

5.7 Conclusion ....................................................................................................................... 130

References: .......................................................................................................................... 132
Table of Figures:

Figure 1: Developmental changes that a child generally adapt prior to walking..........................2
Figure 2: Modelling dimensions of functioning and disability: Child-Environment Interaction (Simeonsson et al. 2003, p.604)..................................................................................................................17
Figure 3: Components of the McCarron Assessment of Neuromuscular Development............28
Figure 4: Components of Age Band 2 of the MABC-2 Test.......................................................31
Figure 5: Consort statement of the recruitment process to completion of assessments.........52
Figure 6: Tasks of the second age band of the MABC-2..........................................................54
Figure 7: Scatterplot from Bland and Altman test for inter-rater reliability of the TIS between tester 1 and tester 2. ...............................................................................................................................62
Figure 8: Scatterplot from Bland and Altman test for inter-rater reliability of the Manual Dexterity Component of the MABC-2 for tester 1 and tester 2.........................................................62
Figure 9: Scatterplot from Bland and Altman test for inter-rater reliability of the Aiming and Catching Component of the MABC-2 between tester 1 and tester 2.................................63
Figure 10: Scatterplot from Bland and Altman test for inter-rater reliability of the Balance Component of the MABC-2 between tester 1 and tester 2.........................................................63
Figure 11: Scatterplot from Bland and Altman test for intra-rater reliability of the TIS between Day 1 and Day 2. .................................................................................................................................68
Figure 12: Scatterplot from Bland and Altman test for intra-rater reliability of the MABC-2 Manual Dexterity Scores between Day 1 and Day 2. .................................................................68
Figure 13: Scatterplot from Bland and Altman test for intra-rater reliability of the MABC-2 Aiming and Catching Scores between Day 1 and Day 2.................................................................69
Figure 14: Scatterplot from Bland and Altman test for intra-rater reliability of the MABC-2 Balance Scores between Day 1 and Day 2.................................................................69
Figure 15: Consort statement of the recruitment process to completion of assessments........92
Figure 16: McCarron Assessment of Neuromuscular Assessment Tool .................................93
Figure 17: Movement Assessment Battery for Children-2 ..........................................................95
Figure 18: Scatterplot of relationship between total scores of the MAND (NDI) versus total scores of the MABC-2 (TIS). ..................................................................................................................104
Figure 19: Children Classified as Motor Impaired by the MAND and the MABC-2.................109
Figure 20: Children Classified as non-Motor Impaired by the MAND and the MABC-2......109
Table of Tables:
Table 1: DSM-IV criteria and amendments adopted at the Leeds consensus statement ..........8
Table 2: Current assessments of Motor Proficiency (McCarron 1982, Wiart and Darrah 2001, Yoon et al. 2006)...........................................................................................................................................................................25
Table 3: Common factors that emerge in tasks within the MAND and the MABC-2.........36
Table 4: Studies investigating the reliability of the MAND ...........................................39
Table 5: Reliability studies of the MABC. ........................................................................42
Table 6: Reliability studies of the MABC-2 ......................................................................47
Table 7: Demographics of the participants in the reliability study ..................................52
Table 8: Inclusion and Exclusion Criteria for participation in the study .........................53
Table 9: Key of strength of Intra-class correlation coefficient (Portney and Watkins 2007) ..56
Table 10: ICCs and Bland and Altman calculations for Inter-rater Reliability ..................59
Table 11: ICCs and Bland and Altman calculations for Intra-rater Reliability .................65
Table 12: Validation Studies of the MAND ......................................................................78
Table 13: Validation studies of the MABC .......................................................................81
Table 14: Validation studies of the MABC-2 Test ...........................................................85
Table 15: Inclusion and Exclusion Criteria for subjects wishing to participate in the study 92
Table 16: Classification of children using the MAND .......................................................94
Table 17: Traffic light system for classifying children using the MABC-2 .......................96
Table 18: Strength of Correlation (Cohen 1988, pp. 79-81 cited in Pallant 2007) .............99
Table 19: Classification of children as motor impaired versus non-motor impaired children according to the MAND and the MABC-2 ..........................................................100
Table 20: Gender and ages of children of the 6 schools who participated in the study .......102
Table 21: Descriptive Statistics (range, mean and standard deviations) for the dependent variables of boys and girls .........................................................................................................................102
Table 22: Spearman’s rho (top) and Pearson (bottom)Cross-Correlation Coefficients (r) between the McCarron Assessment of Neuromuscular Development Factors and the Movement Assessment Battery for Children 2 Subtests (n=114) ..................................................106
Table 23: Case Agreement for Motor Impairment between the McCarron Assessment of Neuromuscular Development (MAND) and Movement Assessment Battery for Children-2 (MABC-2)........................................................................................................................................... 108

Table 24: Performance of Typically Developing versus Motor Impaired Children on all components of the MAND............................................................................................................................................. 110

Table 25: Performance of Typically Developing versus Motor Impaired Children on all components of the MABC-2............................................................................................................................................. 111

Table 26: Common factors hypothesised to emerge in tasks within the MAND and the MABC-2 ......................................................................................................................................................... 115
List of Appendices:

Appendix A: Ethical Permission ................................................................. 141
Appendix B: Request letters and information for schools ............................. 142
Appendix C: Information Leaflets for Parents (Reliability Study) ...................... 144
Appendix D: Information Leaflets for Children (Reliability Study) .................... 147
Appendix E: Consent Form (Reliability Study) ............................................. 148
Appendix F: Information Leaflets for Parents (Validation Study) ..................... 149
Appendix G: Information Leaflets for Children (Validation Study) .................... 151
Appendix H: Consent Forms (Validation Study) ........................................... 152
Appendix I: Data Collection forms .............................................................. 153
List of Abbreviations:

ABD Atypical Brain Development
ADD Attention Deficit Disorder
ADHD Attention Deficit Hyperactivity Disorder
ADHD-C Attention Deficit Hyperactivity Disorder- Combined Type
ADHD- HI Attention Deficit Hyperactivity Disorder- Hyperactive/ Impulsive
ADHD- PI Attention Deficit Hyperactivity Disorder- Predominantly Inattentive
AERA American Educational Research Association
ANOVA Analysis of Variance
BOTMP Bruininks-Oseretsky Test of Motor Proficiency
BOTMP-LF Bruininks-Oseretsky Test of Motor Proficiency- Long Form
BOTMP- SF Bruininks-Oseretsky Test of Motor Proficiency- Short Form
CI Confidence Interval
D Mean
DAMP Deficits in Attention, Motor Control and Perception
DCD Developmental Coordination Disorder
DCD-Q Developmental Coordination Disorder- Questionnaire
DSM Diagnostic and Statistical Manual
ICC Intra-class Correlation
ICF International Classification of Function
ICIDH International Classification of Functioning, Disability and Handicaps
IQ Intelligence Quotient
KTK Korperkoodinations Test fur Kinder
LoA Limits of Agreement
MABC Movement Assessment Battery for Children
MABC-C Movement Assessment Battery for Children- Checklist
MAND McCarron Assessment of Neuromuscular Development
MI Motor Impaired
NDI Neuromuscular Developmental Index
PDMS Peabody Development Scales
PE Physical Education
R Pearson Correlation Coefficient
RD Reading Disability
SD Standard Deviation
SDdiff Standard Deviation of the Mean Difference
SE of d Standard Error of the Mean
SLI Speech and Language Impairments
SPSS Statistical Programme for Social Sciences
WHO World Health Organisation
95% CI 95% Confidence Interval
95% CI of d 95% Confidence Interval of the Mean
Chapter 1 Introduction:

1.1 Introduction to Motor Development in Children:

Significant structural and functional changes occur in the brain throughout our lifespan, with the most profound of these changes occurring in childhood (Diamond 2000). Differentiation of neural networks of the brain occurs with age and development, enabling us to support more specialized perceptual and motor behaviour (Casey et al. 2005). These changes occur in the fronto-parietal coupling to increase motor control in children, particularly between 6 and 10 years of age (Casey et al. 2005), however not all children develop at the same rate as their peers with some experiencing delay in the area of motor development.

Motor development may have been defined as “the process through which a child acquires movement patterns and skills” (Malina 2004, p.50). This process is brought about by the development and continuous modifications of the following characteristics of the individual child: (1) neuromuscular maturation; (2) physical growth and behavioural features of the child; (3) the speed of physical growth, biological maturation and behavioural development; (4) the residual effects of previous movement experiences; and (5) novel movement experiences (Malina 2004). These personal adaptations that the child progresses through occur in the context of the physical, social and cultural environment in which the child is reared. Consequently, these environmental factors are paramount in facilitating the motor development and determining the motor repertoire of the child. Most children, apart from those with severe disabilities, have the capacity to develop and learn a variety of fundamental movement patterns and more specialised motor skills. These motor skills are crucial as they provide a medium through which the child can experience the world and subsequently develop in many areas of personal development such as socially, psychologically, physically and academically (Missiuna et al. 2004, Missiuna et al. 2007, Cairney et al. 2009, Skinner and Piek 2001).

The term “developmental milestone” is very common when referring to the development and maturation of a child. Within a physical context these milestones often denote the acquisition of control and coordination of specific voluntary movements during infancy and throughout childhood. These milestones form an integral part of developmental scales which are often used as screening instruments to identify children with impeded motor development who may
be at risk of having a developmental disability. Age-associated variation for the attainment of exact motor milestones during infancy and early childhood are crucial as they give an indication of overall motor development that infants and young children are expected to demonstrate at specific ages (Malina 2004). An example of these developmental milestones throughout infancy and childhood include the locomotion of the child which typically follows a general sequence of events, primarily mediated through postural adaptations and development (Figure 1).

**Figure 1: Developmental changes that a child generally adapt prior to walking**

By about five years of age an adult walking pattern should be established in the majority of children and subsequent to this independent locomotion increasing experimentation with a variety of movements are possible (Malina 2004). Previous and current literature surrounding
motor development describes the temporal, spatial, and sequential elements of specific movement patterns as they develop through childhood. These elements are summarised as the child progresses from an immature to a mature pattern for each of these fundamental motor skills. Although when studies group the trends and performance of children in achieving these motor milestones a continuous trend is formed, however, when investigating the development of an individual child many deviate from this normal trend (Malina 2004).

Experimentation of the child into new movement patterns leads to proficiency in basic motor tasks which are the foundation of more complex physical activities. A primary example of this within the school environment is running and throwing. These tasks must be mastered individually first, once this is achieved the skills can be combined to competently participate in games such as rounders. This motor development facilitates many other areas of the child’s development including; increased physical development, along with psychosocial and emotional through the interaction with classmates.

Currently, the most prominent framework within the area of motor development is the dynamical systems theory (Thelen et al. 1994, Lewis 2000, Thelen and Adolph 1992). This system encompasses the interaction of the child, the environment and the motor task. These components are interconnected and continuously changing. Motor development is thus the outcome of the interaction of the developing child, the specific motor tasks and the environment in which the child interacts. The terms body scaling and action scaling are often used in the context of dynamical systems. When examining the child-environment interactions body scaling encompasses the changing body dimensions and proportions whilst action scaling includes the improving levels of motor competence. As the child grows the body size, proportions and composition change, simultaneously, as the child develops the level of motor proficiency changes, consequently these influence the mature of the interactions between the child and the environment.

1.2 Statement of the problem

However, many children experience motor difficulty and subsequently do not achieve motor milestones. These children who experience poor motor development and experience motor difficulties are often diagnosed with having a developmental delay known as Developmental Coordination Disorder (DCD). However, there is still a large degree of uncertainty in the terminology surrounding this diagnosis and many other terms are used to describe these group of children, a common term being children with “movement difficulties” (Cummins et
However, what is agreed across all terminology when referring to children with poor motor development is children experiencing a primary problem in motor development that impacts on other areas of development and function (Rivard et al. 2007, Sugden 2006). Although there are some discrepancies in the terminology used to describe children with poor motor development, much of the literature has adopted the term DCD, hence this shall be the terminology used within chapter one when referring to most recent research surrounding motor difficulties and subsequent assessments of children.

During early childhood years, learning is achieved through doing within the school environment. It is here that a child with DCD may experience most problems, hence, this is the environment in which these children should be screened (Missiuna et al. 2004). Given the importance of mastering basic motor skills to facilitate further motor proficiency and the role of the environment in this motor development it is crucial that it is within the natural environment in which children interact on a daily basis that the motor competencies of children are investigated. However, most research being conducted with children are being administered within a clinical setting and many problems which children experience within their daily environment are being overlooked.

Furthermore, most assessments were originally designed to be administered in quiet, clinical environments facilitating optimal achievement as opposed to the regular daily environment of the child. Thus these assessments may not be deemed ecologically valid and may not identify children with genuine motor deficits who experience difficulties daily with basic functional motor tasks. Another factor to be considered is the ability of these assessments designed to identify the same children with motor deficits to accurately conduct this exact function within the classroom environment. Subsequently, the above issues shall be the foundation of this study and will be addressed throughout the course of the review. Also, to be confident in the results obtained by any assessment it is of utmost importance that it has established strong psychometric properties, primarily reliability and validity, consequently these properties must be investigated.

1.3 Justification of study

Given the poor routine screening of motor development of children here in Ireland as in many other countries worldwide and given the high prevalence of motor difficulties in children it is
crucial that screening instruments that can be administered efficiently within the context of the child’s daily environment are developed.

It is important that these assessments are administered within the context of the child’s regular environment given the strong interaction between the child and the environment in the process of motor development (Thelen et al. 1994). Also, it is important that children experiencing these motor difficulties are identified at an early age to enable intervention to be implemented as soon as possible. This early intervention is crucial in preventing some of the secondary problems associated with poor motor development including reduced self-esteem, social isolation, poor physical health and poor academic achievement (Missiuna et al. 2004, Missiuna et al. 2007, Cairney et al. 2009, Skinner and Piek 2001).

However, to enable accurate screening of children within their regular, dynamic environment accurate, versatile and economical assessments are necessary. Two possible assessments which are easily administered and contain tasks that may be required of the child on a regular basis include the McCarron Assessment of Neuromuscular Development (MAND) and the Movement Assessment Battery for Children-2 (MABC-2). However, to be confident that these assessments are suitable to be administered ecologically within the school environment this process must be investigated. Furthermore, the psychometric properties of these assessments must be established within this particular environment encompassing an ecological validity.
1.4 Thesis Objectives:

Given the high prevalence of motor delay experienced by children in mainstream schools, the lack of regular screening and the large co-morbidities associated with these initial developmental motor delays, implementing assessments within schools is crucial. However, screening can only be implemented by identifying psychometrically strong, ecologically valid assessments. Subsequently, the objectives of this study were:

1. To conduct a comprehensive literature review into DCD and problems surrounding DCD within the classroom environment.

2. To investigate theoretical frameworks of motor assessments and review the psychometric properties of some common assessments used to identify children with motor difficulties.

3. To investigate the inter- and intra-rater reliability of the two assessments that were chosen; the MAND and the MABC-2 within an ecologically valid environment.

4. To investigate the convergent validity of the MAND and the MABC-2 within the school environment.

5. To determine the decision agreement between the MAND and the MABC-2 in identifying children with motor impairments.

6. To investigate which tasks within the MAND and the MABC-2 are strong at distinguishing between typically developing and motor impaired children.
Chapter 2: A literature review of Developmental Coordination Disorder in children and the importance of accurate screening assessments within mainstream schools enabling diagnosis.

2.1 DCD

Developmental coordination disorder (DCD) is a marked impairment in motor coordination that does not have identifiable neurological or sensory problems (American Psychiatric Association 2000). Historically, children presenting with DCD have been called ‘clumsy’ or may have been diagnosed with ‘developmental dyspraxia’. However, in October 1994 researchers and clinicians from around the world agreed to adopt the term DCD to classify this population at an international consensus meeting and classified it according to the Diagnostic and Statistical Manual (DSM) -IV criteria (Polatajko et al. 1995). This classification was discussed further with the proposal of a number of clarifications and amendments in the Leeds Consensus Statement (Sugden 2006) (Table 1). The amendments of the Leeds Consensus statement primarily centre on standardisation in the measurement of each of the four criteria for the diagnosis of DCD. It puts a particular emphasis on criteria B which establishes whether the motor impairments experienced by the child interfere with their activities of daily living. This important aspect of the child’s development has also been highlighted as the crucial component within the World Health Organisation’s International Classification of Functioning, Disability and Health framework (WHO, 2001). Within this WHO framework it was recommended that focus should be on the activity performance and participation component rather than body structure and function. They felt that reduced activities of daily living were primary indicators of deviations in motor development. With this area of the child’s daily function so crucial it is of upmost importance that the motor abilities of the child are investigated within the context in which these activities are being performed everyday incorporating these activities of daily living.
Table 1: DSM-IV criteria and amendments adopted at the Leeds consensus statement

<table>
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<tbody>
<tr>
<td>Criterion A</td>
<td>“Performance in daily activities that require motor coordination is substantially below that expected given the person’s chronological age and measured intelligence. This may be manifested by marked delays in achieving motor milestones (e.g., walking, crawling, and sitting), dropping things, “clumsiness”, poor performance in sports, or poor handwriting.” (DSM-IV-TR, 2000 p.58)</td>
<td>Recommend use of individually administered, culturally appropriate, norm referenced test of motor competence and apply this criterion with scores below the 5th percentile. (Observational tools may be used as an initial screening tool).</td>
</tr>
<tr>
<td>Criterion B</td>
<td>“The disturbance in criteria A significantly interferes with academic achievement or activities of daily living.” (DSM-IV-TR, 2000 p.58).</td>
<td>Assessments should reflect culturally relevant developmental norms relating to activities of daily living tasks and should include consideration of self-care, play, leisure and schoolwork (including handwriting, PE and tool use) and the views of the child, parents, teachers and relevant others. (Sugden 2006 p.5)</td>
</tr>
<tr>
<td>Criterion C</td>
<td>“The disturbance is not due to another general medical condition (e.g. cerebral palsy) and does not meet the criteria for a pervasive Developmental Disorder.” (DSM-IV-TR, 2000 p.58).</td>
<td>A conventional neurological examination should be conducted to rule out major neurological conditions e.g. definite disorders of posture, tone and reflexes. (Sugden 2006 p.5)</td>
</tr>
<tr>
<td>Criterion D</td>
<td>If mental retardation is present, the motor difficulties are in excess of those usually associated with it. (DSM-IV-TR, 2000 p.58).</td>
<td>Ideally, a measure of IQ should be made to establish the general level of intellectual ability. Where this is not feasible a teacher’s opinion or other relevant data such as national tests are acceptable. (Sugden 2006 p.5)</td>
</tr>
</tbody>
</table>

Estimates of the prevalence of DCD in a primary school population are 6%, highlighting this condition as a significant problem within this vulnerable group (American Psychiatric Association 2000, Missiuna et al. 2006c). This percentage is the equivalent of approximately
one child in every class. Studies have found that the disorder is much more prevalent in boys than in girls with ratios ranging from 2:1 (American Psychiatric Association 2000), to a much higher ratio of 5:1 in teacher-identified samples (Missiuna et al. 2006b). Thus, the actual gender ratio is very variable depending on the method of assessments employed in different circumstances.

The etiology of the condition is being continuously investigated, however due to the heterogeneity of DCD this process is very complicated and a definitive causality is not possible (Hoare 1994, Missiuna et al. 2006b). It had originally been speculated that DCD may have been caused by a minor brain insult, such as cerebral palsy, implying that minor neurological dysfunction was the cause of these motor difficulties (Barnhart et al. 2003, Missiuna et al. 2006b). Some experimental research is now hypothesizing cerebellar dysfunction which is inhibiting the child’s ability to make motor processes automatic while others are investigating the presence of clusters of minor neurological dysfunction as a possible causality (Missiuna et al. 2006b, Hadders-Algra 2003).

DCD is an extremely heterogeneous condition with many variations in the motor deficits presented by each individual. Due to this complex presentation, numerous attempts have been made to classify the various presentations into specific subtypes (Hoare 1994, Macnab et al. 2001, Green et al. 2008). The aforementioned studies support the assumption that five patterns of dysfunction emerge using cluster analysis. These subgroups briefly consist of:

1. Good balance
2. Good visual-motor
3. General Perceptual-motor
4. Poor fine motor/ visual motor
5. Poor gross motor

These five clusters emerged when six of the same factors were investigated within the studies. This finding highlights the importance of an in-depth, robust assessment of this diverse population to investigate the various aspects of motor performance that may be impaired with DCD (Barnhart et al. 2003). However the inconsistency among standardised motor tests used to identify children with DCD is a problem as it may cause many discrepancies in the various motor abilities of the individual child. An example of this may include a test that focuses too
much on fine motor competencies of the child may either positively or negatively influence the child’s overall motor performance depending on the child’s strengths and weaknesses.

2.1.1 Co-morbidities:

The variations in the individual presentations of each child with DCD include impaired motor ability as its primary problem but also include other areas of physical, intellectual and social capacity of the child. Although it is important that motor assessments are conducted on children suspected of having DCD, it is vital that the wider spectrum of overall ability and everyday performance of the child is also examined. The more common co-morbidities include attention deficit disorder (ADD), attention-deficit-hyperactivity disorder (ADHD), reading disability (RD) and speech and language impairments (SLI) (Crawford and Dewey 2008, Gaines and Missiuna 2007, Piek et al. 2004, Kaplan et al. 1998, Watemberg et al. 2007, Piek and Dyck 2004).

Although there is often one feature of these children’s difficulties that stands out from all others it is rarely the case that it is an entirely isolated problem.

(Kaplan et al. 1998, p.472)

This statement has proven paramount for children with DCD as numerous studies outline that co-morbidity is rule rather than exception and can present simultaneously or sequentially within this population. Kaplan et al. (1998) investigated a group of 115 children and only 53 were identified as ‘pure cases’ showing signs of DCD, RD or ADHD. Another crucial finding within this study was of the remaining 62 ‘co-morbid cases’ 23 had difficulties in each of the areas outlined above. This overlap between specific learning difficulties and other problems has been established by a number of other researchers (Pitcher et al. 2003, Kaplan et al. 1998, Visser 2003). DCD has been described in the context of the child experiencing overall learning difficulties as opposed to a specific deficit in a particular developmental area;

‘generalized deficit, instead of a pure language, attention or a co-ordination problem’

(Visser 2003, p.484).

Some of the theories that aim to gain an understanding of DCD and its co-morbidities include ABD: The atypical brain development hypothesis, DAMP: The ‘deficits in attention, motor control and perception’ hypothesis and the automatization deficit hypothesis (Visser 2003, Gillberg 2003). The DAMP concept encompasses combinations of motor control and
perceptual problems along with attention problems. It has been suggested that children with DAMP meet the criteria of DSM-IV ADHD and developmental coordination disorder (Gillberg 1998). Studies have investigated the strength of this theory by investigating the prevalence of DCD in a population of children with ADHD (Piek et al. 1999, Pitcher et al. 2003). Both of these studies investigated the subtypes of ADHD, namely: ADHD predominantly inattentive type (ADHD-PI); ADHD predominantly hyperactive/impulsive (ADHD-HI); and ADHD, combined type (ADHD-C). Both studies found that approximately half children presenting with ADHD had motor performance problems and that it was primarily children with an inattention component to their ADHD that experienced more difficulties with fine motor tasks. The reasoning for this common finding was that fine motor skills require sustained attention and effortful activity. A study investigating 866 sets of monozygotic twins also found that there was more ADHD concordance than discordance within the sets of twins and that 9 sets of twins presented with both DCD and ADHD (Pearsall-Jones et al. 2008). Given the fact that in reality co-morbidity is the norm rather than the exception within this population, it is of upmost importance that a multi-modal assessment is implemented by the relevant clinicians or primary carers for this child (Wilson 2005).

Secondary co-morbidities are also common in this population of children with DCD. Movement difficulties that the child may experience can lead to negative secondary consequences (Hamilton 2002). These difficulties are usually obvious to parents at a very early age (Missiuna et al. 2006b) and visible to peers once the children achieve school years (Cairney et al. 2005). An evolution has been described from simple motor and play concerns in initial years, progressing to more complex self-care, academic and peer-related difficulties in middle childhood (Missiuna et al. 2004). These motor and functional deficits develop into emotional and social problems such as reduced self-esteem, social isolation and emotional health issues once children reach the school years (Missiuna et al. 2007, Chen et al. 2009). It has been shown that difficulties experienced by children with DCD within a school population may persist into adulthood and expand into psychological problems including anxiety, depression and lowered self-esteem (Skinner and Piek 2001). In addition to the social and emotional health issues that this child may have due to difficulties participating in group activities and integrating into peer settings, this child is also predisposed to numerous physical co-morbidities. The DSM-IV criteria for DCD suggest motor in-coordination as a major characteristic of this population who consequently experience as impediment to
physical activity. This compromised physical activity has enormous repercussions to physical health of the child considering the inter-relationships between activity, cardio-respiratory fitness, body fat and coronary vascular disease (Faught et al. 2005, Hay et al. 2004).

2.1.2 Diagnosis:

Historically, parents had been encouraged not to worry about their child’s presenting clumsiness and the child would outgrow the problem. However longitudinal studies investigating the progression of DCD children into adolescence and adulthood have shown that it does not simply subside. One such study was a controlled, longitudinal, community-based study that looked at children with DCD or ADHD at age 7 and again at 22-years of age (Rasmussen and Gillberg 2000). These children were found to have more criminal offences, incidences of substance abuse and other psychiatric disorders, along with lower levels of schooling. Subsequently, with these co-morbidities inevitable and proof that DCD does not simply ‘disappear’, it is vital that an early diagnosis of this condition is obtained to facilitate the implementation of early intervention for the child (Missiuna et al. 2006b).

Along with the importance of an early diagnosis on the part of the child, it is also paramount to the psychological wellbeing of the parent. Parents generally are the first to detect these motor deficits in their infants and young children and despite the parents knowing their child is experiencing motor difficulties, they are unable to receive a concrete diagnosis, creating a burden of anxiety (Missiuna et al. 2006c). It has been estimated that parents of school aged children with DCD often consult with ten or more health and educational professionals in search of an explanation of their child’s motor difficulties (Missiuna et al. 2006c). Therefore, it is of enormous relief to these parents when their child receives a diagnosis as this allows them to seek closure through advocating for their child. This can be achieved through the implementation of important treatments and also increasing the awareness within the school environment to ensure necessary adaptations are made where necessary with the ultimate goal of preventing the development of avoidable secondary complications (Missiuna et al. 2006b).

Although it is important to get an early diagnosis of DCD to allow for implementation of early intervention, it is of upmost importance that all children are not labelled with a single symptom profile and treated accordingly. Children with DCD need a combination of services to provide a holistic approach to the assessment and subsequent treatment of their diverse movement difficulties (Wilson 2005). This is evident when looking at the various sub-groups of DCD that emerged in the studies investigating cluster analysis (Hoare 1994, Macnab et al.
These 5 subgroups were further identified in a cross-over intervention study (Green et al. 2008). Within this study no advantage was conferred to any subtype, although a general finding was that children with more complex presentations at initial assessment, despite making progress during intervention, displayed continuing difficulties at the end of the project. Although this study provided intervention to each of the clusters, this intervention was not modified for each cluster or furthermore for each individual with various co-morbidities. Consequently, the lack of a holistic approach to the treatment encompassing the different difficulties that individual children experience may have influenced the benefits of the therapy. This study illustrates the importance of motor assessments to capture this variability, allowing individual motor profiles to emerge, facilitating more individualised intervention. The evolution of these sub types also illustrate the importance of capturing performance through studying subtest profiles as opposed to total scores in isolation (Wilson 2005).

Although it is clear that DCD and similar developmental disorders are a growing concern, particularly in the earlier years of child development a study has revealed that knowledge of these conditions within the healthcare and educational settings is exceptionally low (Kirby et al. 2005). This remarkably low level knowledge of these conditions may be a crucial contributing factor to the under diagnosis of many children with DCD (Missiuna et al. 2008). This study by Kirby et al (2005) found that teachers and particularly General Practitioners have very limited knowledge of very common developmental disorders, including DCD. As outlined earlier in the DSM-IV there are four diagnostic criteria that must be achieved for a diagnosis of DCD. Physicians have a role in ruling out other possible explanations for the child’s motor coordination problems; however the absence of other medical conditions that would explain coordination problems is only one of the four diagnostic criteria (American Psychiatric Association 2000). Meanwhile, both physiotherapists and occupational therapists are extremely well positioned to conduct the motor assessment necessary for criteria A and through the implementation of necessary instruments can address the impact of motor impairment on activities of daily living and/or academic activities (Missiuna et al. 2008). Although physiotherapists and occupational therapists should be instrumental in the role of assessing children within the normal school environment, this is not the case in Ireland and many other countries. Although a large proportion of this under diagnosis may be contributed to a lack of resources within governmental departments to fund such motor assessments, other issues which have been investigated in an occupational therapy context (Missiuna et al.
2008) may also be viable within a physiotherapy context, and thus should be addressed. These barriers to conducting assessments included; limited personal knowledge of DCD, reluctance to engage in a process that leads to a child receiving a label, a belief that it is possible to make the underlying impairment go away, fear about overstepping professional boundaries and fear that the physician may not know enough about the diagnosis of DCD. Each of the barriers outlined above can be overcome through advocating for both the health and educational professionals to increase their personal knowledge of DCD. It is also crucial for the therapist to be aware of the importance of ‘labelling’ or diagnosing this child to allow for early intervention, thus preventing numerous secondary consequences to DCD.

Although physiotherapists and occupational therapists ultimately have a key role in identifying children with DCD, it is important to realise the crucial role that classroom teachers, other educational professionals and parents can have in implementing screening assessments to identify these children. According to the Leeds Consensus Statement on DCD as a specific learning difficulty it was outlined that observational checklists may be used as an initial screening tool for identifying children with possible DCD (Sugden 2006). The important role of teachers, parents and other individuals in close proximity on a daily basis with the child in completing these screening instruments will be outlined later.

2.1.3 Early intervention:

It is important firstly to note that the primary objective of most physiotherapeutic and other therapeutic intervention is not to change the child’s motor abilities but essentially to prevent the onset of secondary physical, social, emotional and academic problems (Missiuna et al. 2004). Numerous papers including literature reviews along with systematic reviews have addressed the enormous role of physical intervention, primarily physiotherapeutic intervention, within this population (Wilson 2005, Hillier 2007, Barnhart et al. 2003, Mandich et al. 2001). All the literature is comparable regarding the most appropriate treatment and management of children with DCD stating that the heterogeneity of this disorder makes best practice difficult to establish as no single approach often works for all children (Mandich et al. 2001).

Within this population of children with DCD, the management should focus on the extent to which treatments improve the child’s motor performance in daily activities as opposed to concentrating on the achievement of developmental milestones seen in a normally developing child (Mandich et al. 2001). It is concluded that assessment and subsequent intervention
should be strategic, being ‘theoretically-principled, thus, construct-valid but also flexible enough to cater for individual differences in presentation, learning style and progress’ (Wilson 2005, p819). This finding is paramount when addressing this population due to the numerous theories surrounding motor development within this population along with the varying presentation of each individual child. These theories are implemented in approaches used to assist children with DCD to establish more skilled action in home and school based activities (Hillier 2007).

According to studies investigating intervention with children with DCD and in accordance with international consensus meetings it has been agreed that intervention should be holistic, child-centred and individualized for the unique characteristics of the child (Polatajko et al. 1995, Hillier 2007). Moving on from this, treatment approaches employed by physiotherapists can be broadly categorised into either bottom-up or top-down approaches (Barnhart et al. 2003). Bottom-up approaches are based on hierarchical theories of motor control and hypothesise remediation of motor dysfunction via activation of higher levels of neuronal functioning in a child. More elaborately, this occurs through the selective transmittal of sensory information, which the central nervous system interprets and organises into the development of an appropriate movement strategy (Barnhart et al. 2003). This form of intervention is based on neuromaturational theories. Primary examples of this approach to intervention include sensory integration therapy, process-orientated treatment, perceptual motor training and a combination of these (Mandich et al. 2001). Alternatively, the top down approach emphasises on cognitive or problem-solving skills to select and implement the most appropriate strategies for successful task performance. This approach has been greatly influenced by the dynamic systems approach to motor learning. This system addresses both internal and external components of the child’s behaviour, along with the influence of environment on the child’s performance. Examples of this include task-specific intervention and cognitive approaches (cognitive orientation to performance in daily activities).

A further study evaluated the current approaches to intervention in children with DCD (Sugden 2007). This study investigated the various models of intervention and from theoretical, empirical and experimental perspectives concludes six guidelines that incorporate a combination of cognitive, dynamic and ecological perspectives. These are outlined as follows:
• The child should be actively involved in all aspects of intervention from goal planning to self-monitoring.

• Functional activities relevant to the activities of daily living for that child should be prioritised.

• These functional activities should be taught as specific skills while allowing for generalisation of the specific skill to different situations.

• Approaches utilised should be evidence-based from the motor learning and control literature.

• The intervention should be ecologically viable and should be incorporated into the family routine.

• A team of people including therapists, teachers and family should be actively involved in the implementation of the intervention.

The results of these studies were summarised in a systematic review which has a general consensus that intervention per se is better than nothing for children with DCD (Hillier 2007). This review found strong evidence for several approaches including sensory integration therapy, perceptual-motor therapy, kinaesthetic training and specific skill intervention. However, the author felt that results should be interpreted with caution due to the studies that noted a negative or nil effect of physiotherapeutic intervention. Although most of the high level evidence suggests that physiotherapy intervention is of benefit, there is a paucity of studies investigating the pragmatics of intervention delivery. Other areas that should be addressed include modes of intervention such as education and awareness, ecological change or enrichment of current environments. The top down approach has been found to be more effective within this population of children with DCD as it looks at the interaction of the child within their normal environment and focuses on important tasks and goals that the child needs to accomplish to participate successfully within this environment (Barnhart et al. 2003). Thus this form of physiotherapeutic intervention is a more ecologically valid treatment. Similarly to this ecological intervention, it is also important that assessments are ecologically valid to correctly identify difficulties that the child may experience on a regular daily basis, such as in the classroom environment. This aspect of validity is discussed in greater depth later in this review.
2.1.4 Link DCD to School environment:

The International Classification of Functioning, Disabilities and Handicaps (ICIDH) have emphasised that disability is not uni-dimensional but manifests at different levels of human functioning in the form of impairments, performance limitations and the experience of disadvantage (Simeonsson et al. 2003). When looking at the abilities of a child it is important to also look at the environment in which the child interacts. This child-environment interface causes a shift in the framework of child abilities from a medical to a broader biopsychosocial assessment of disability. This was illustrated through the application of the International Classification of Function (ICF) framework model to the interaction between the child and the environment (Figure 2).

![Diagram of Child-Environment Interaction](image)

*Figure 2: Modelling dimensions of functioning and disability: Child-Environment Interaction (Simeonsson et al. 2003, p.604)*

This diagrammatic representation of the World Health Organisation (WHO) framework highlights how the physical ability of the child can impact hugely on the child’s interaction within the environment. This individual-environment interaction can have a detrimental impact on the participation of the child if necessary environmental adaptations and support
networks are not implemented from an early stage. One particularly pertinent environment that must be closely examined when dealing with children is the classroom environment.

In an environment that emphasises learning through “doing”, children with DCD generally fall short of their potential because they have coordination difficulties that impact their academic, social and physical maturation and development (Misiuna et al. 2004). DCD is a motor impairment that affects a child’s ability to perform coordinated, skilled movements necessary for daily functioning such as academic and self-care tasks. Subsequent to this upon looking specifically at the school environment, almost every activity, particularly in the early years, is a motor activity varying from academic learning through writing and doing, to social participation and interaction with peers. Consequently, for children demonstrating coordination problems, active participation in academic activities with a motor component poses an enormous challenge and necessitates a tremendous effort by the child to complete the task. This difficulty extends beyond the classroom setting to the whole school environment as these children may have difficulty firstly getting prepared for recess and secondly participating in activities during this time (Misiuna et al. 2006a, Hamilton 2002).

Evidence of the presence of motor difficulties interfering with functional performance of children within the school environment is as shown in a Canadian study which found that 50% of teachers had referred children suspected of having motor impairments to occupational therapists at 8 years and 80% by the age of 10 (Miller et al. 2001). The referral of these children was primarily due to handwriting and fine motor difficulties that were interfering with the child’s performance in school.

Further typical classroom problems that may present with this group include balance difficulties, fatigue and inability to maintain good sitting postures for long periods of time (Misiuna et al. 2004). Subsequent to lack of successful participation within and outside of the classroom environment, what originated as simple coordination difficulties can quickly exacerbate into more complex social and emotional problems for the child.

Although it is the individual child with DCD that carries the burden of an inability to cope with these motor problems, DCD may also have an impact on the classroom as a whole. Disruptions in the classroom are common as children with DCD may knock things over, drop objects or bump into other children’s desks. Along with disruption of the class or activity it may impede on the learning of other class members or worse it may inadvertently cause harm to another student. It is also important for a teacher to be aware of the strong association
between motor problems and other coexisting behavioural and developmental problems, with a 50% likelihood of DCD in the presence of other developmental delays (Missiuna et al. 2004). It is imperative that these children are identified and then teachers are aware of the implications of the coexistence of these disorders. It is important that the presence of motor issues is addressed when alternative methods of teaching are implemented with children with learning impairments. It has been found that children with DCD in addition to ADHD have a poorer outcome than children with ADHD alone (Tervo et al. 2002). As it has been found that the motor difficulties of children with DCD do not spontaneously disappear, it is crucial that children learn to cope with the demands of the classroom environment in a way that encourages maximal learning and participation.


This basic right of the individual child can be implemented through the medium of a classroom teacher once the child has been correctly identified as having motor deficits (Missiuna and Ont 2003, Henderson et al. 2007). However, to ensure an accurate diagnosis can be made, it is important that the motor abilities of children are assessed in their normal environment during the developmental years (Simeonsson et al. 2003).

This screening within the regular, daily classroom environment of the child may be described as ecologically valid. Similarly to the top down ecological intervention, motor assessments should too be as close to the ‘way of life’ as is realistically possible (Henderson et al. 2007). However, this screening can only be accurately conducted through the administration of diverse, ecologically valid assessment tools with strong psychometric properties.

### 2.2 Ecological Validity:

Ecological validity may be described as the degree of representativeness of a task and the generalisability of test results (Burgess et al. 2006). The degree of representativeness of the task refers to the extent to which the test corresponds in form and context to a situation encountered outside the laboratory. Meanwhile, the generalisability of the test results is the degree to which poor performance on the test will be predictive of problems outside of the testing situation. Subsequent to this description, it is clear that ecological validity focuses on
what the client does in his or her everyday, not what the client can do within an artificial testing environment (Chaytor and Schmitter-Edgecombe 2003). Thus, to get the child’s optimal performance the testing would be conducted in an artificial, clinical environment to eliminate several distractions.

More specifically, according to the administration guidelines outlined in the testing manuals, this environment is typically quiet, with few distractions; the examiner prompts task initiation and completion, provides one-on-one instruction and is supportive regardless of success or failure (McCarron 1982, Henderson et al. 2007). This is however not representative of how the child would perform on daily tasks within the home, or more importantly within the classroom environment where children must often perform competitive tasks under distractive and unsupportive conditions. Consequently, testing under these artificial conditions would decrease the generalisability of these test results, reducing the ecological validity of the assessments administered.

Ecological validity will be maximised by using familiar materials and collecting data in familiar environments (Zittel 1994). Attending to these key features will ensure that more accurate information regarding functional skill level is being collected. It is also important that people most familiar to the child (caregivers/teachers) should be part of the testing environment and present at the time of administration. Teachers may be more appropriate within a classroom situation as they are the normal figures present within the classroom setting.

Other aspects of ecological validity that must be considered when assessing motor abilities of children include 1) the sample of behaviour that is being analysed and 2) compensatory strategies that may or may not be employed under these specific testing conditions. The assessment only gathers a minute sample of a person’s behaviour in a single environment; this may not be representative of the motor behaviours of the child over a longer period of time in slightly varying situations. These short testing environments also provide limited information about the child’s endurance and response to fatigue (Chaytor and Schmitter-Edgecombe 2003). Another concept to consider within artificial testing situations is the inability of a child to implement compensatory strategies that they may use everyday to complete tasks effectively. This may result in failure of the child in this area of motor performance within the test, whilst the child may be completing a similar motor task successfully daily through use of compensatory strategies. Both of these issues reflect the
importance of looking ‘outside the box’ by investigating the child’s motor abilities in a
different format to the implementation of a stringent motor assessment at one specific
moment in time.

A method that could be implemented to address the ecological validity of these motor
assessments would be the use of qualitative questionnaires, such as the Movement
Assessment Battery for Children Checklist (MABC-C) or the Developmental Coordination
Disorder Questionnaire (DCD-Q). These assessments are questionnaires that are completed
by teachers or primary caregivers who observe all aspects of the child’s behaviour, including
motor behaviour, on a daily basis (Schoemaker et al. 2003, Schoemaker et al. 2006, Faught et
al. 2008, Kourtessis et al. 2003). Through investigating the correlation between results
obtained by the children on these questionnaires and the results achieved on the motor tests,
the investigator can establish if these tests are ecologically valid and representative of the
child’s daily performance within the home, or more specifically to this study, within the
classroom environment. This was true when comparing the MABC test to the MABC-C, as
the concurrent validity of these instruments has been established in a group of 184 children
aged 6 to 11 years presenting both with and without motor deficits (Schoemaker et al. 2003).

A more comprehensive look at the specifics of ecological validity highlights various
dimensions of ecological validity including; Nature of research setting or context, Nature of
the stimuli and Nature of the task, behaviour or response (Schmuckler 2001). Firstly, the
nature of the research setting or context is a key issue regarding the ecological validity of an
assessment. It is crucial that the setting contains features of naturalistic settings ideally it
should be the true environment in which the children perform their motor abilities on a daily
basis. The next dimension to be considered is the nature of the stimuli used in the process of
assessing the motor abilities of the child. This involves both the construct validity of the
instrument and the stimuli that the child may gain through the encouragement and feedback
of the assessor.

With each assessment used to investigate the motor competencies of a child, it is vital that all
aspects of validity are established, including construct validity. This is to ensure that the tasks
included within the assessment are developmentally appropriate tasks that actually measure
the various aspects of motor abilities that it aims to assess (Wilson 2005). Therefore, with
these assessments, it is important to establish the nature of these stimuli (assessments) and
what they can tell us about the child’s motor abilities. This can be established through determining convergent and discriminant validity (Wilson 2005).

Finally, nature of the task, behaviour or response refers to how the child reacts to the testing situation. This dimension is similar to the first, in that it is important that the testing conditions are in a naturalistic setting, to allow the child to be more relaxed and respond to each task in a similar manner that would occur in an everyday situation (Chaytor and Schmitter-Edgecombe 2003). Specific components of neuromuscular coordination that have been investigated for ecological validity in clinical versus natural environment include perception of surface rigidity, depth perception, intermodal perception, balance control, visually guided locomotion and spatial orientation (Schmuckler 2001).

2.3 Assessments of Motor Competence of Children:

2.3.1 Theoretical basis of types of assessments used:
Subsequent to the uncertainty surrounding the etiology and diagnosis of DCD, approaches to assessment of this population vary with each drawing on distinct theoretical assumptions about the etiology of the condition and its developmental course (Wilson 2005). These approaches to motor assessment can be divided according to their explanatory framework or proposed etiology into the following categories: normative functional skills approach, general abilities approach, neurodevelopmental theory, dynamical systems theory and the cognitive neuroscientific approach.

- The general abilities approach is based on the assumption that sensory-integrative and sensorimotor functions provide the platform for later motor and intellectual development, thus movement difficulties are incurred when there are organisational difficulties between these functions. Physiotherapists and occupational therapists are commonly involved in this form of assessment.

- The neurodevelopmental theory is a broad approach to assessment and is predominantly employed within the medical profession based upon the assumption that there are neuromaturational deficits in the child’s development.
The dynamical systems approach is a relatively new framework to motor assessment and is based on the dynamical systems theory (Thelen and Bates 2003). This process is thought to involve multiple, cooperative systems that coexist within the developing child and their interaction with the task and the constraints of the environment. The assessments implemented in this approach include observational analysis, biomechanical analysis and task-specific analysis.

Finally, the cognitive neuroscience approach is based on the hypotheses of deficits in the internal modelling of movement and deficits in motor training predisposing the child to deviations from normal development.

Although there is some evidence to support each of these approaches to motor assessment, the normative functional skill approach remains the most commonly implemented movement assessment (Wilson 2005). This form of assessment has broad conceptual roots with theoretical viewpoints of Gesell, McGraw and Piaget forming the framework for the assessment (Wilson 2005). It is based on the acquisition of sensorimotor and cognitive milestones, stages of maturational change along a time course of normal development and the role of constructivism. Accordingly, descriptive assessments are used, based on the acquisition of fundamental motor and functional skills which are compared to age-related norms.

These descriptive tests are largely concerned with the outcome of a specific movement, “Has the movement goal been achieved accurately and in a timely manner?” Therefore, these tests should also yield a quantitative measure which can be derived through response time, proficiency rating, and error and accuracy scores and gets a better indication of performance level and motor competence in each area. To evaluate whether the child is developing normally, these performance scores are generally compared to age related norms. Two of the more popular assessment tools used to test motor impairment of children four years or above are the MABC (Henderson and Sugden 1992) and the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) (Bruininks 1978) (Missiuna et al. 2006d).

It is important when choosing assessment tools to distinguish between diagnostic tests and screening tests, as these vary depending on the purpose of the assessment (Wilson 2005). Diagnostic tests are designed to provide clinical information about movement competencies which is subsequently used to create an individualised treatment programme. Screening tests, on the other hand, are used to identify children at risk for developmental problems. Other
screening instruments that can be used in collaboration with tests of motor impairment, incorporating the normative functioning approach, include checklists such as the MABC-C or the DCD-Q. These checklists can serve as screening tools implemented prior to or in conjunction with motor tests such as the MABC.

Although assessment tools such as the MABC and the BOTMP have proven successful in the assessment of children with motor impairments, at the construct level there is a need to adopt a lifespan perspective on motor development. There is a need for a motor assessment that adopt common tasks across all age groups thus enhancing the reliability of changing scores over time and inter-age comparison. An example of one such test that assesses both fine and gross motor tasks using common tasks for ages ranging from 4 years to adults is the McCarron Assessment of Neuromuscular Development (MAND) (McCarron 1982).

Finally, outcome measures should ideally capture individual differences in proficiency, avoiding floor and ceiling effects and ideally be indexed on a continuous scale, such as time to completion. This would enhance the power of discrimination for test items and their sensitivity to developmental change over time (Wilson 2005).

2.3.2 Investigation of current assessments used within a classroom setting and psychometric properties of these assessments:

Given the importance of detection of children both at an early age and within their natural environment, it may be derived that the optimal solution would be to implement screening with a young population within mainstream schools. It is crucial that this daily child-environment interface is the setting in which the assessments are conducted to facilitate a shift in the framework of child abilities from a medical to a broader biopsychosocial assessment of disability as was outlined in the ICF framework model (Simeonsson et al. 2003). Subsequently, the testing environment should simulate that of a regular classroom environment and the assessment instruments should be suitable with this population.

Screening tests in education are vital to provide a quick assessment of the child as they can examine a large population quickly to determine if further assessment should be conducted as they do not necessarily involve individual administration (Piek 2006). Issues to be considered when choosing assessments include; recommended uses of assessments, ages with which the assessments are to be administered and time to administer assessments (Table 2).
<table>
<thead>
<tr>
<th>Assessment Name</th>
<th>Description of assessment</th>
<th>Age</th>
<th>Time to administer</th>
<th>Recommended uses</th>
<th>Recommended Populations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement Assessment Battery for Children -2</td>
<td>Norm referenced test of gross and fine motor abilities.</td>
<td>3-16 years</td>
<td>20-30 minutes</td>
<td>Identification and screening, intervention planning, program evaluation and as a research tool with children at risk of motor difficulties.</td>
<td>Screening for children at risk of motor difficulties.</td>
</tr>
<tr>
<td>McCarron Assessment of Neuromuscular Development (MAND)</td>
<td>Norm referenced test of fine and gross motor abilities of children.</td>
<td>3.5-18 years</td>
<td>15-20 minutes</td>
<td>Screening, evaluation and research tool for clinicians, therapists and researchers.</td>
<td>Screening assessment for children at risk of motor difficulties.</td>
</tr>
<tr>
<td>Peabody Developmental Motor Scales (PDMS)</td>
<td>Criterion and norm referenced test to establish the developmental skill level of a child.</td>
<td>0-6 years</td>
<td>20-30 minutes</td>
<td>Identification, screening, program planning, research tool, evaluation for children suspected of having motor co-ordination difficulties.</td>
<td>Particularly for children between the ages of 18 months and 3 years due to limited availability of gross motor assessment tools for this age.</td>
</tr>
<tr>
<td>Bruininks-Oseretsky Test of Motor Proficiency (BOTMP)</td>
<td>Norm referenced test of fine and gross motor abilities.</td>
<td>4.5-14.5 years</td>
<td>45-60 minutes</td>
<td>Assess motor skills of children, develop and evaluate motor training programmes; identify motor dysfunctions and developmental handicaps.</td>
<td>Children and individuals with learning disabilities, developmental handicaps and dysfunctions.</td>
</tr>
<tr>
<td>Tufts Assessment of Motor Performance</td>
<td>Assess three major domains of ability; mobility, activities of daily living and communication.</td>
<td>6 years - adult</td>
<td>45-60 minutes</td>
<td>Identification, screening and providing comprehensive assessments of motor skills underlying physical disabilities and functional limitations.</td>
<td>Assessment of varying populations of all ages.</td>
</tr>
<tr>
<td>Test of Gross Motor Development</td>
<td>Assess motor skills typically taught in physical education</td>
<td>3-10 years</td>
<td>15-20 minutes</td>
<td>Identification, screening programme planning, evaluation, research tool.</td>
<td>Children suspected of having motor co-ordination problems.</td>
</tr>
</tbody>
</table>
There are numerous instruments used to assess the motor proficiency of children, some of the more common assessments include the Movement Assessment Battery for Children, The McCarron Assessment of Neuromuscular Development, The Peabody Development Scales (PDMS) and the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP). Two less popular assessments include Tufts Assessment of Motor Performance and Test of Gross Motor Development. As the Test of Gross Motor Development only investigated gross motor abilities and had a narrow age spectrum with which it could be administered it was eliminated. Tufts assessment of Motor performance was too in-depth for the purpose of looking at the motor abilities of numerous children within a school population no further analysis was conducted on the assessment.

For each of the other four assessments further analyses into studies investigating the psychometric properties of each assessment was conducted. Numerous studies have investigated further properties of each of these assessments including aspects of reliability and validity.

The BOTMP is the most commonly used diagnostic test used by therapists within a clinical setting to allow for the development of specific intervention (Wilson 2005). Although the BOTMP is a popular assessment within a clinical setting, its use as a screening instrument is debatable due to its questionable reliability and validity (Crawford et al. 2001, Tan et al. 2001). The poor screening properties of the BOTMP when compared to the MABC and the MAND was identified through it’s poor sensitivity (31%) when compared to the MAND (81%) for the identification of children with motor impairments (Tan et al. 2001). A further finding within this study was the adoption of a less stringent cut-off score of the 40th and 50th percentile did not alleviate this inability to identify children with developmental coordination disorder. Of greater concern when identifying children with DCD is the inability of the BOTMP to measure impairment in terms of quality of the movement. This is vital as it has been shown that children with DCD may complete tasks through the implementation of compensatory poor quality movements and at a slower speed than age norms (Missiuna and Pollock 1995).

The PDMS is another assessment used to screen children for the presence of developmental motor delay. The main focus of the PDMS is on assessments and subsequent intervention planning for children with disabilities (Cools et al. 2008). It estimates the child’s motor
competence relative to his or her peers based on normative data. This movement assessment tool measures both gross and fine motor skills, and is comprised of 6 subtests; four investigating gross motor skills while two involve fine motor skills. The original PDMS (Folio and Fewell 1983) was revised to the PDMS-2 which was published in 2000 (Folio and Fewell 2000). Although the revised version is very similar to the original PDMS-2, it contains several improvements including; expanded normative data, established reliability and validity, new scoring criteria and illustrations to clarify assignments (Cools et al. 2008). However, many limitations occur to the application of this assessment as a screening tool within a mainstream school setting. The most pertinent issue is that it assesses children from birth to 6 years, thus it would not be suitable for most children attending mainstream schools. Also, it would not be as economical as other assessments regarding time of administration, 40-60 minutes (Cools et al. 2008). It has also been suggested that further standardisation is necessary because of dependence on observer interpretation (Vanvuchelen et al. 2003). Finally, when compared to the popular MABC the PDMS-2 was found to be less sensitive in identifying 4 and 5 year old children with motor impairment (Van Waelvelde et al. 2007a).

Although each of the above assessments has various unique qualities, with different advantages and disadvantages, given the ease of administration within a dynamic school population and availability to the researcher for the purpose of this study the focus shall be on two of the more suitable screening tests, the MABC and the MAND. One of the primary functions of each of these assessments is as a screening instrument to distinguish between normally developing children and children with DCD. Some of the advantages and disadvantages of each of these assessments shall be outlined, including the psychometric properties of the assessments.

2.3.2.1 MAND:

In comparison to their age-matched peers, children with DCD display poorer fine and gross motor skills (Piek et al. 2006, Skinner and Piek 2001). As, the MAND has a comprehensive set of fine and gross motor tasks it is one of the primary assessment tools that should be used to screen this population. Also, one of the primary purposes of the MAND is as a screening procedure in child education to identify children with potential developmental disorders (McCarron 1982). The MAND assesses the fine and gross motor performance of 3.5-18 year-olds, evaluating both qualitative and quantitative aspects of motor performance. The test consists of 10 motor tasks; 5 gross motor tasks and 5 fine motor tasks (Figure 3). Fine motor
tasks involve both the separate and co-ordinated use of hands, as well as impulsivity, distractibility and extraneous body movements. Meanwhile, gross motor tasks investigate the coordinated movement of the entire body in a standing position, as well as the capacity to integrate kinaesthetic cues and demonstrate effective muscle power skills (McCarron 1982). These ten tasks are common across all age groups, this commonality of tasks for all age brackets from 3.5-18 years of age is a positive quality of the MAND as it enhances the reliability of changing scores over time and inter-age comparison (Wilson 2005).

Figure 3: Components of the McCarron Assessment of Neuromuscular Development

Children obtain raw scores during the test depending on how they performed on conducting the various tasks. The MAND is a norm-referenced test (Piek 2006), therefore appropriate age related tables of norms are utilised to convert raw scores to scaled scores. These scores represent each child’s performance in comparison to their age-matched peers. Developmental norms for the MAND were derived from a sample of over 2,000 healthy individuals 3.5 years of age to young adults (McCarron 1982). The developmental norms for children ages 3 through 12 are based on 6 month intervals, whilst the developmental norms above 12 years follow a more gradual progression consequently one-year intervals are used. The Neuromuscular Developmental Index (NDI) is considered a general measure of motor skills and is determined by first summing the scaled scores for each of the 10 tasks and then converting this sum to the NDI.
Due to the many areas in which a child can experience motor difficulties (Macnab et al. 2001), it is important to investigate sub-components of the child’s performance as opposed to looking at the overall scores and viewing the motor ability of the child based upon a single number. Another area that can be investigated within the MAND is factors i.e. looking at subsets of the MAND that are significantly correlated. These tasks share the common factor variance and are used to measure the same factor of hypothetical construct. The four main factors within the MAND have been found to be Persistent Control, Muscle Power, Kinaesthetic Integration and Bimanual Dexterity. Factor scores are based on a distribution with a mean of 100 and a Standard Deviation of 15 (McCarron 1982). An individual’s factor scores can be directly compared to each other and/or to the NDI to determine the relative strengths and/or deficits in particular neuromuscular skills. Within the context of this study, these factor scores may also be important as they may emphasise specific motor areas within the normal classroom environment that children may experience motor difficulties.

The intra-rater reliability of the MAND after a one month interval ranges from 0.67 to 0.98 (McCarron 1982). This was investigated within a population of adults with intellectual disabilities and thus could not be directly assumed within a healthy paediatric population. However, a recent study investigated both the inter- and intra-rater reliability of the MAND within a healthy paediatric population in a mainstream school (Connell 2010). This study revealed a high reliability both for inter- and intra-rater reliability within this particular population after a one month interval. The validity of the MAND has been established both in an adult (McCarron 1982) and paediatric population (Tan et al. 2001). Within the later study the MAND was found to have strong screening properties with a high sensitivity in detecting motor impairments. However, a recent study investigating the concurrent validity of the MAND against the original MABC questioned this validity (Brantner et al. 2009).

The main advantage of the MAND is its use of common tasks for all ages 3-18 years increasing the reliability of the results obtained across age groups and allowing for easier comparisons between ages (Wilson 2005). Another positive aspect of the MAND is it’s high sensitivity as a screening tool (Tan et al. 2001), it’s ability to measure the child’s motor proficiency from very low to high and it’s ease of administration only taking approximately 20 minutes per child (McCarron 1982). The primary disadvantage of the MAND is its limited use within research in previous years, consequently there a paucity of information.
surrounding the psychometric properties of this instrument within a paediatric population (McCarron 1982).

2.3.2.2 MABC:

The MABC on the other hand is the most commonly reported norm-ranked assessment used to determine the presence of DCD in school-aged children (Johnston and Watter 2006). The MABC is a minimal task set designed to screen for motor impairment rather than provide a profile of a child’s motor performance. It is used for assessing whether a child’s motor function is age-adequate and for identifying children whose motor function deviates from normal development, but lacks neurological signs, i.e. DCD (Gard and Rösblad 2009). The original version of the MABC was a standardised regulated test where quantitative measures such as time and number of successful attempts were recorded for various items involved. It is comprised eight tasks which form three broad motor skill categories including; manual dexterity, aiming and catching, and balance. There are four age bands each with eight tasks forming the three categories but with slightly different tasks in each age band.

Inter-rater and test re-test reliability was also established for the MABC (Chow and Henderson 2003, Van Waelvelde et al. 2007b, Croce et al. 2001, Gard and Rösblad 2009, Smits-Engelsman et al. 2008). The concurrent validity of the MABC was determined through correlations with broad based tests (Croce et al. 2001, Tan et al. 2001, Van Waelvelde et al. 2007a) and through correlations with focused tests (Smits-Engelsman et al. 1998, Van Waelvelde et al. 2004).

2.3.2.3 MABC-2

The MABC was revised to generate a “reliable, easily administered and valid measure of competence in three broad and carefully selected areas of motor performance” (Henderson et al. 2007, p117). To produce the new version of the MABC old items were revised and there were some new items added.

The MABC-2 tests the motor competence of children aged 3-16 years and unlike the MAND, this test is divided into three age bands. These age bands are 3 to 6 years, 7 to ten years and 11 to 16 years. Within each age band there are eight tasks, 3 manual dexterity, 3 aiming and catching and 2 balance tasks (Figure 4). For each of the three components of the test Manual
Dexterity, Aiming and Catching and Balance - and for the total score, age adjusted standard scores and percentiles are provided (Henderson et al. 2007).

**Figure 4: Components of Age Band 2 of the MABC-2 Test**

Each item is rated on a 6 point rating scale, where 5 equates to the weakest performance and 0 is the optimal performance. These standard scores are converted to percentiles which are subsequently compared to age related norm percentiles to detect the presence of motor deficits. These percentiles are comparable to the NDI scores equated within the MAND. Developmental norms for the MABC were established on children from Canada, the United States, and the United Kingdom (Henderson and Sugden 1992). Updated normative data was gathered using 1172 children from Great Britain and Northern Ireland between 2006 and 2007. It involved children from all age bands from 3-16 years and the sample was stratified for geographic region, population density, social class and race or ethnicity (Henderson et al. 2007). The MABC has been translated in to several European languages and is extensively utilised internationally with norms also evaluated in Sweden, Japan, Netherlands, Hong-Kong and Singapore (Brown and Lalor 2009) and Australia (Livesey et al. 2007).

This revised version of the MABC contains a qualitative component which involves analysis of the learning context, the resources of the child, the task to be learned and the context in
which the learning takes place (Gard and Rösblad 2009). This aspect of the test allows the therapist to supplement the numerical scores of the performance test with clinical observations. This new version looks at the bodily control and the demands of the environment separately and how they can influence the environment. This qualitative component of the MABC-2 is similar to the descriptive aspects on the scoring of the gross and fine motor subtests of the MAND, with both looking at aspects such as jerky movement, speed and accuracy of performance and posture (McCarron 1982, Gard and Rösblad 2009).

Some of the primary advantages of the MABC is its availability in several European countries, its cross cultural validity and its simple test administration which facilitates large sample screening over a short period (Cools et al. 2008). Another advantage of the MABC, when compared to the MAND, is the comprehensive body of evidence surrounding the strong psychometric properties of the original MABC. The primary disadvantage of this assessment is the variation in the 8 tasks in each of the three age bands as this may reduce the reliability of changing scores over time and consequently inter-age comparison (Wilson 2005). Another disadvantage of the original MABC was the presence of a ceiling effect with the original MABC in the ‘jumping in squares’ and ‘hopping in squares’ subsets of the test resulting in a lack of discriminative power (Van Waelvelde et al. 2004, Miyahara et al. 1998). However, within the revised version of the MABC these are changed to a similar but new task “hopping on mat” (Henderson et al. 2007) which may eliminate this limitation by being more difficult to complete accurately. Finally, due to the inability of the MABC to distinguish children above the 25th percentile, the scores the child achieves prior to conversion to percentiles may have to be implemented in this study.

The primary disadvantage of the revised version of the MABC-2 is limited preliminary evidence surrounding the reliability and validity of the MABC-2. In a review of the MABC-2 it was found that evidence of validity of the MABC cannot be generalised to the MABC-2, as the tests of the two versions are quite different (Brown and Lalor 2009). However, within the manual the authors describe how they established the content validity, face validity and subtest correlations of the revised version of the MABC (Henderson et al. 2007). The test-retest reliability of the MABC-2 is said to be established within the manual (Visser and Jongmans 2004, Chow et al. 2002, Faber and Nijhuis van der Sanden 2004). However, the
studies by Visser et al (2004) and Faber and Nijhui-Van der Sandens (2004) are unpublished, thus their methodology is unknown and may be questionable.

### 2.3.3 Justification for selection of assessments

#### 2.3.3.1 MAND

- One of the primary purposes of the MAND is as a screening procedure in child education to identify children with potential developmental disorders.

- It is designed for clinical and research purposes.

- The ten tasks of the MAND assess a wide range of motor skills which are required by the child to participate in classroom and physical activities on a daily basis.

- The MAND is small and portable allowing it to be easily transported from school to school.

- The MAND is quick and easy to administer so it does not impede on too much school time.

- It is a norm referenced assessment which allows for a range of motor proficiency from poor to good to be evaluated.

- The MAND was found to have high sensitivity in identifying children with motor impairment, which is vital within a school environment.

- The MAND was found to have good reliability with children within mainstream schools (Connell 2010), however further studies investigating areas of construct validity of the assessment are warranted given the conflicting findings of previous studies (Brantner et al. 2009, Tan et al. 2001).

#### 2.3.3.2 MABC-2

- The MABC-2 was also designed as a screening instrument for identification of children with developmental motor delay within both clinical and research contexts.

- The test is quick and easily administered making it economical within the school environment, facilitating large sample screening over a short period.
• The MABC-2 is robust and portable allowing for easy transportation from school to school.

• This new, revised version of the MABC-2 is colourful, aesthetically appealing and enjoyable for children to complete.

• The MABC-2 is norm referenced allowing for comparison of a child’s performance against typically developing peers and identifying the various motor abilities of children from poor to good. This updated normative data was collected within Britain and Northern Ireland, where the performance of children would be anticipated to be very similar to children within the current study in the Republic of Ireland.

• The MABC-2 is a revised version of the MABC which was extremely popular within several European countries and has extremely strong psychometric properties, therefore it would be anticipated that the MABC-2 would have similar properties.

• The following adaptations were made to the original MABC to increase the strength of the assessment as a screening instrument;
  
  o It is made of plastic which is more robust than wood and overcomes wear and tear from repeated administration.
  
  o Slight changes were made to tasks following previous validation studies of the MABC with the intention of increasing correspondence, sensitivity and consistency of test items of the different age bands.
  
  o Test instructions were clarified to reduce ambiguity in test administration and scoring.

• Given that the tasks included within the MABC-2 are based on functional tasks they are useful in indicating the ability of the child in various areas of motor performance from manual dexterity to ball skills on a daily basis.

• Similar to the MABC strong psychometric properties would be anticipated for the MABC-2, however there is a paucity of evidence surrounding its reliability and construct validity warranting further investigation.
The MABC-2 has a checklist which can be useful for screening purposes particularly within the school environment where the teacher’s perception of a child’s motor performance can be compared to the clinicians’ findings according the MABC-2 test.

### 2.3.4 Comparison of structure and content of the MABC-2 and the MAND

Some of the structural differences between both assessments include;

- Specific tasks for each of the three age bands of the MABC-2 versus one set of tasks for the MAND.
- The MAND is comprised of 10 tasks whereas the MABC-2 is comprised of 8 tasks.
- Although both tasks look at fine and gross motor abilities of the child the MAND is divided into 2 groups; gross and fine motor tasks, whereas the MABC-2 test has 3 groups; manual dexterity, aiming and catching, and balance tasks.

Although each of the assessments outlined above vary slightly in structure and content, their primary aim is similar and thus they should each have the ability to measure the motor competence of children, identifying the same children with motor impairments.

Although these discrepancies in the content and structure of the assessments exist, when the motor abilities assessed within each task of both assessments is studied it is apparent that each the four factors that emerge in the MAND are similar to tasks within the MABC-2. These tasks are used to measure a similar factor of hypothetical construct ranging from persistent control to kinaesthetic integration (Table 3).
Table 3: Common factors that emerge in tasks within the MAND and the MABC-2

<table>
<thead>
<tr>
<th>Factor</th>
<th>MAND Task</th>
<th>MABC-2 Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bimanual Dexterity</td>
<td>Nut and Bolt Beads on Rod</td>
<td>Threading lace Catching with 2 hands</td>
</tr>
<tr>
<td>Persistent Control</td>
<td>Rod Slide Finger-Nose-Finger</td>
<td>Drawing Trail</td>
</tr>
<tr>
<td>Strength</td>
<td>Grip strength Hopping*</td>
<td>Hopping on mats*</td>
</tr>
<tr>
<td>Kinaesthetic Integration</td>
<td>Heel-to-toe walking on line* Standing on one leg*</td>
<td>Walking heel-to-toe forwards* One-board Balance*</td>
</tr>
</tbody>
</table>

*These tasks are common to both assessments*

Another task common to both assessments is the manual dexterity assessment. Within the MAND this involves the use of one hand to place beads into another box, whereas in the MABC-2 this again involves using one hand to place pegs on a board. Both dominant and non-dominant hands are assessed in both.
Chapter 3: The inter- and intra-rater reliability of the MABC-2 when administered in an ecologically valid environment.

3.1 Introduction:

To be confident in the results obtained after administration it is vital that an assessment has strong psychometric properties. Two of the most common and pertinent of these properties include the reliability and validity of the assessment. It is said that adequate reliability is a prerequisite to obtaining validity (Anastasi 1988). The Standard for Educational and Psychological Testing puts the responsibility jointly on the test developer and test user to determine and establish the reliability and validity of tests (AERA. et al. 1999). Subsequently the test user is ultimately responsible for evaluating information of reliability proposed by the developers in relation to their own situation. Hence, this chapter shall focus on the importance of having reliable assessments of motor development. The reliability of the assessments being implemented in the validation study will be formulated by investigating previous literature into then reliability of the assessments, determining their applicability to the current study and carrying out subsequent research as necessary.

The reliability of a scale can vary depending on the sample with which it is used. Thus, it is of utmost importance that the reliability of an assessment is determined within the specific population that it will be implemented within (Pallant 2007). In this particular thesis the assessments that will be employed in the larger study are the MAND and the MABC-2 and the population that they will be administered on are children aged 7 and 8 attending mainstream rural schools in Ireland.

Two studies have been conducted to investigate the reliability of the MAND (See Table 4). The first study investigated the reliability of the MAND within a sample of 31 intellectually impaired adults (McCarron 1982). Although the results of this study demonstrated a high test-retest reliability of the MAND, methodological limitations outlined in table 3 below reduce the generalisation of this study to an intellectually intact paediatric population. However a more recent study investigated the inter- and intra-rater reliability of the MAND with 6-8 year old children in mainstream rural primary schools (Connell 2010). The study was conducted using a similar protocol to that employed in this particular study with children being assessed in groups of three within their normal school environment, thus optimising the ecological validity of the assessments. The inter-rater reliability was good intra-class correlation (ICC) was 0.85 and the intra-rater reliability was slightly weaker (ICC= 0.83).
Both of these reliabilities are acceptable with ICC ≥.75 (Portney and Watkins 2007), thus the reliability of the MAND did not have to be investigated further with the population included in the validation study.
<table>
<thead>
<tr>
<th>Study</th>
<th>Type of Reliability</th>
<th>Population/Sample</th>
<th>Setting</th>
<th>Results</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connell 2010</td>
<td>Intra-rater reliability</td>
<td>20 children from first class in a primary school in West Cork, Ireland.</td>
<td>Tested twice by the same tester at the same time and in the same environment with an interval of 7 days between testing. Tested by different testers on the same day in the same environment with an hour interval between administrations of the tests.</td>
<td>Intra-rater Reliability for total NDI scores; ICC .83, 95% CI .59 → .94. Inter-rater Reliability for total NDI scores; ICC .85, 95% CI .59 → .94.</td>
<td>Only children in first class were included in this sample reducing the generalisation of these results to children of different ages. Small sample size reduces the external validity and ability to generalise the results of this study.</td>
</tr>
<tr>
<td>McCarron 1997</td>
<td>Test-retest Reliability</td>
<td>31 Mentally Impaired adults</td>
<td>Assessed by the same tester with an average of one month interval between both assessments.</td>
<td>High reliability was found: - Subtest correlations varied from .67 → .99. - Total test-retest correlations .99 -Total standard error of measurement 16.4</td>
<td>Difficult to generalise the results obtained in the current study to an intellectually intact paediatric population. Test-retest coefficients were the statistical analysis used as opposed to the more appropriate intraclass correlation coefficients for determining reliability.</td>
</tr>
</tbody>
</table>
3.1.1 Types of reliability:

Reliability is the property of reproducibility of the results of a measurement procedure or tool (Polgar and Thomas 2008). Furthermore, there are numerous different ways in which reliability can be investigated and established. These include test-retest reliability, intra-rater reliability and inter-rater reliability. Within this section the areas of inter-rater reliability and intra-rater reliability of the MABC-2 will be discussed and investigated further.

3.1.1.1 Inter-rater reliability:

Inter-rater reliability is important to establish due to the inconsistencies that can exist between clinicians upon administering assessments with specific regard to paediatric motor delay. Poor agreement between clinicians can lead to discrepancies between clinicians regarding decisions on whether the child has a motor developmental delay or not. Also, subsequent to a child being diagnosed with a motor impairment it may be necessary for the child to see different clinicians. The potential poor agreement can limit the ability to identify patient deterioration or progress if their assessment results are not consistent with other clinicians.

This form of reliability is generally determined by having two or more clinicians independently assessing the same patients on the same occasion and then comparing results (Polgar and Thomas 2008). If the agreement between these results are high then a high inter-rater reliability is said to be present for that assessment, however if there is a low level of agreement between results, the assessment has a poor inter-rater reliability.

3.1.1.2 Intra-rater reliability:

Intra-rater reliability on the other hand is the agreement between results obtained when the test is administered on two separate occasions by the same examiner. This aspect of reliability is important within the clinical setting to measure an individual’s progress or deterioration over a period of time when measured by the same examiner. This could include establishing if a particular intervention is improving the motor skills of a child (Mannisto et al. 2006, Wright and Sugden 1998, Watemberg et al. 2007) or contrary to this could be used in longitudinal studies to establish if the motor abilities of children improve or deteriorate as they progress though the school system (Connell 2010). Another advantage of establishing this type of reliability includes that it allows clinicians to conduct a child’s motor assessment
over two days if necessary. This can be useful to account for a child’s “good” and “bad” days in clinical practice and give a more accurate and reliable illustration of the child’s motor capacity. This can be determined through use of the child’s mean performance over the two days in deciding the motor competence of that child (Croce et al. 2001).

This form of reliability can be established by one assessor administering the same test on two separate occasions (Polgar and Thomas 2008). If there is high agreement between the results obtained on the two separate occasions, high intra-rater reliability is said to be present and vice versa if the agreement is low.

3.1.2 Previous Reliability studies of the MABC test:

The original version of the MABC is a standardised regulated test where quantitative measures such as time and number of successful attempts are recorded for various items involved (Henderson and Sugden 1992). As this test was one of the most popular assessments of motor development in children there was much research conducted utilising the MABC, including numerous investigations into its psychometric properties. Five studies that established the reliability of the original MABC are outlined in Table 5 below.
Table 5: Reliability studies of the MABC.

<table>
<thead>
<tr>
<th>Study</th>
<th>Type of Reliability</th>
<th>Population/Sample</th>
<th>Setting</th>
<th>Results</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gard &amp; Rosblad, (2009)</td>
<td>Inter-rater Reliability</td>
<td>12 children with different motor abilities were divided into 3 groups (Cerebral Palsy, DCD and Normal)</td>
<td>Assessed by a qualified physiotherapist on 2 aspects of the MABC while being videotaped, videos sent to and assessed by 18 Physiotherapists and Occupational Therapists.</td>
<td>Inter-rater reliability is moderate to high (ICC=0.75) for two items combined, but low correlation for the manual dexterity item on its own.</td>
<td>Difficult to distinguish children with DCD from normally developing children. Was difficult to see, thus analyse, movements in different dimensions on the video-tape, especially the manual dexterity item. Small sample size of children.</td>
</tr>
<tr>
<td>Smits-Engelsman, Fiers, Henderson &amp; Henderson (2008)</td>
<td>Inter-rater reliability</td>
<td>9 children aged 4-12 years with motor difficulties, one child representing each intervening year, who had been referred for motor assessments</td>
<td>Each child was videotaped while they were assessed using the MABC in a quiet room. 131 physical therapists watched and rated the child’s motor performance upon observing then video tapes. Compared extent to which physical therapists agreed</td>
<td>Agreement among raters was good with an average mean difference in Total Impairment Score (TIS) of 1.9 points and the classification of children into normal, at risk or definitely</td>
<td>Some items were repeated if the therapist did not see it the first time. This would not be possible in a clinical situation. Difficult to analyse movements in different dimensions due to videotape.</td>
</tr>
</tbody>
</table>
| Van Waelvelde et al (2007) | Inter-rater reliability | 33 4 and 5 year old children with poor motor performance (24 boys/ 9 girls). | Children were tested 3 times by one trained examiner with an interval of 3 weeks between each assessment. Each test was repeated on the same weekday, at the same time and in the same quiet room for each child. | ICC of TIS (ICC = 0.88) with a CI of 0.79-0.93 indicating good reliability.  
ICC of balance scores good (ICC = 0.82), Manual Dexterity moderate (ICC = 0.75) and ball skills were poor (ICC = 0.45).  
ICC’s of individual item scores varied from low-high (ICC = 0.14→0.81).  
Kappa co-efficient between the three tests were 0.72, indicating | Some assessors were not familiar with each of the age bands of the MABC if they are primarily working with a specific age band of children. | It is thought that a practice effect may have occurred between the second and third testing, especially on items evaluating ball skills. |
| **Chow and Henderson (2003)** | Inter-rater Reliability | Intra-rater reliability | Tested in the familiar surroundings of their schools.  
Inter-rater reliability: both testers were present in the room and scored each child’s performance simultaneously but independently. Half the children were tested by one tester while the other observed and half by the second tester.  
Intra-rater reliability: testing was carried out by one tester a minimum of 2 weeks and a maximum of 3 weeks apart. | Inter-rater reliability: Overall mean ICC very high (ICC = 0.96). ICC’s of individual items ranged from ICC = 0.74-1.00.  
Perfect agreement between testers on the classification into no impairment or motor impairment (above or below the 5th percentile).  
Intra-rater reliability: Overall mean ICC = 0.77 (p<0.001). Individual ICC’s were moderate to good for all items except for the rolling ball item at age 6. | Children were found to be practicing some of the tasks themselves between assessments, thus influencing the reliability of the study. |
|---|---|---|---|---|---|
| **Inter-rater reliability** | 79 randomly selected children aged 4-6 years from mainstream pre-schools.  
Intra-rater reliability: 75 randomly selected children aged 4-6 years from mainstream pre-schools.  
16 children took part in both parts of the study. | 75 randomly selected children aged 4-6 years from mainstream pre-schools. |  |  |  |
| **Croce, Horvat & McCarthy (2001)** | **Intra-rater Reliability** | 106 children aged 5-12 years (67 boys/ 39 girls) were recruited from 4 mainstream elementary schools. Each child tested individually twice within one week. | High intra-rater reliability for all age groups ICCs = 0.92 → 0.98. | Re-test was conducted within one week therefore a learning affect may have occurred with some of the children and enhancing the consistency of the results. Study did not discuss the reliability of the scores achieved for sub- or individual components of the MABC. These may have varied greatly between tests. |
The above studies demonstrate that the original MABC had good to excellent intra-rater and inter-rater reliability. The ICC’s for the Total Impairment Scores were found to be higher than the ICC’s obtained for the 3 components and 8 individual tests for each age band (Van Waelvelde et al. 2007b, Chow and Henderson 2003).

Although the reliability of the MABC was found to be good to excellent within most of these studies, some methodological limitations were identified which could have influenced the results.

Within the studies investigating inter-rater reliability most of the raters viewed the motor performance of the child through the medium of a tape (Gard and Rösblad 2009, Smits-Engelsman et al. 2008). A limitation of analysing the motor performance of a child using this method is that it is only uni-dimensional and is consequently difficult to analyse the movements of the child in different dimensions. This was found to be particularly pertinent for the manual dexterity components of the MABC (Gard and Rösblad 2009). A further limitation was that if the therapist failed to see the performance on the first occasion the videotape was repeated occasionally (Smits-Engelsman et al. 2008). This reduces the clinical significance of the findings of this study, as the therapist will not get to view the exact same performance of a child on two occasions.

The other inter-rater reliability study implemented a more realistic and ecologically valid approach to the assessment (Chow and Henderson 2003). Both raters were present while the assessment was conducted and rated the child simultaneously but independently. This is simulating the actual assessments and context in which they will be performed. Another advantage of the methodology within this study was that the tests were conducted in the child’s familiar school environment, thus maximising ecological validity.

Within the intra-rater reliability studies the primary limitation that was highlighted was a practice effect that occurred between assessments (Van Waelvelde et al. 2007b, Chow and Henderson 2003). A learning effect was also proposed to have occurred in the study that conducted the assessment with only a one week interval between assessments (Croce et al. 2001). Consequently, an interval of greater than one week would be preferable.

A positive attribute of the intra-rater reliability study conducted by Van Waelvelde et al. (2007) is that most were conducted on the same day, at the same time and in the same environment, thus increasing the stability and the reproducibility of the results.
### 3.1.3 Reliability of the MABC-2 test:

#### Table 6: Reliability studies of the MABC-2

<table>
<thead>
<tr>
<th>Study</th>
<th>Type of Reliability</th>
<th>Population/Sample</th>
<th>Setting</th>
<th>Results</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visser, Jongmans &amp; Volman (2004)</td>
<td>Intra-rater reliability</td>
<td>55 3 year old children assessed using age band one of the MABC-2</td>
<td>Tested twice by the same tester with a mean interval of 11 days between testing.</td>
<td>Pearson’s product moment correlations revealed;</td>
<td>Only the first age band investigated and only with 3 year olds. Study is not published, therefore the methodology is unknown. Pearson’s correlation co-efficient used for analysis is not preferable form of analysis as does not determine absolute reliability.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- A low correlation of $r = 0.49$ for aiming and catching task.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Posting coins, catching and balance were marginally reliable ($r = 0.65-0.68$).</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Threading beads, drawing trial and static balance all met the $r = 0.70$ criterion of adequacy.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Intra-rater reliability was low for the non-preferred limb (may be due to fatigue or boredom as this is performed second).</td>
<td></td>
</tr>
<tr>
<td>Chow, Chan, Chan and Lau (2002)</td>
<td>Intra-rater and inter-rater reliability</td>
<td>31 subjects aged 11-16 years assessed using age band three of the</td>
<td>Assessed by three final year occupational therapy students who were trained by the first</td>
<td>Inter-rater reliability were excellent (ICC = 0.92→1.00). Intra-rater reliability varied from good to excellent (ICC = 0.62 → 0.92).</td>
<td>Reliability of triangle with nuts and bolts component was not outlined.</td>
</tr>
<tr>
<td>Study</td>
<td>Intra-rater and inter-rater reliability</td>
<td>Sample Size</td>
<td>Methodology</td>
<td>Findings</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>----------------------------------------</td>
<td>-------------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Faber &amp; Nijhui- Van der Sandens (2004)</td>
<td>Intra-rater reliability</td>
<td>64 young adults aged 18-28 years assessed using age band three.</td>
<td>14 assessed twice by the same tester (intra-rater reliability) 16 were tested again by a different tester (inter-rater reliability).</td>
<td>Intra-rater and inter-rater reliability of ICC = 0.79 for this smaller sample for total scores obtained on the test. For larger sample (n=64) for scoring above or below the 15&lt;sup&gt;th&lt;/sup&gt; percentile; intra-rater reliability (0.79-100% agreement) and inter-rater reliability of 88-100% agreement.</td>
<td></td>
</tr>
<tr>
<td>MABC-2</td>
<td>author, the translator of the MABC into Chinese and a very experienced tester. Inter-rater reliability: child was assessed by one tester and was observed and scored independently by a second tester. Intra-rater reliability component: All children were tested two weeks later by the same tester.</td>
<td>Walking backwards task was performed perfectly by nearly all children on the second occasion making statistical analysis of the test-retest reliability difficult and indicative of a ceiling effect of this assessment with it being too easy and possibility of a learning affect with only one practice.</td>
<td>MABC-2 designed for 3-16 year olds, this study included subjects above the upper limit of the normative sample. Only third age band investigated. Study not published.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The original MABC was revised to generate a “reliable, easily administered and valid measure of competence in three broad and carefully selected areas of motor performance” (Henderson et al. 2007, p117). Above are some of the reliability studies that have been conducted on this revised version of the MABC-2 (Table 6). Although the authors declare that the revised version of the MABC assess the same motor skill constructs, revisions to the instrument essentially make MABC-2 a different instrument (Brown and Lalor 2009). This is especially pertinent for the second age band in which two age bands of the MABC were amalgamated to produce a single age band for children aged 7 though to 10 years old (Henderson et al. 2007).

Upon analysing the above studies it is clear that the reliability of this revised version of the MABC is quite good however there are some limitations within these studies and furthermore with their application to this present study. The primary limitation to the application of the MABC-2 clinically is that the second age band has not been investigated in any of these studies. For this reason further research is deemed necessary and the focus of this particular study is to investigate the inter- and intra-rater reliability of the second age band of the MABC-2.

Another issue is the inability to analyse the methodology used by the researchers in these studies as two of the three studies have not yet been published (Visser and Jongmans 2004, Faber and Nijhuis van der Sanden 2004). With these limitations in mind, it is crucial that a reliability study involving the second age band is undertaken to determine both the inter-rater and intra-rater reliability of the MABC-2 prior to conducting the validation study.

A large methodological limitation of all of these reliability studies is none have reported utilising Bland and Altman calculations to investigate the absolute reliability of the MABC or the MABC-2. This makes the clinical significance of the finding within these studies questionable as Bland and Altman Calculations are the most appropriate form of statistical analysis (Rankin and Stokes 1998).
3.2 Aims/ Objectives:

3.2.1 Aim:
To determine both the inter-rater and intra-rater reliability of the Movement Assessment Battery for Children-2 (MABC-2) with children aged 7-9 years.

3.2.2 Objectives:
1. To investigate whether the MABC-2 is a reliable assessment of motor development in a population of children aged 7-9 years when administered by two different trained assessors on the same occasion.

2. To investigate whether the MABC-2 is a reliable assessment of motor development in a population of children aged 7-9 years when administered on two separate occasions by the same assessor.

3.2.3 Hypothesis:
As much of the construct and contents of the revised MABC is similar to that of the original version with only a few small modifications it was hypothesised that the MABC-2 would have similar psychometric properties to the original MABC. Given the strong psychometric properties of the original MABC, including high inter-rater and intra-rater reliability (Chow and Henderson 2003, Van Waelvelde et al. 2007b, Croce et al. 2001, Gard and Rösblad 2009, Smits-Engelsman et al. 2008), it was anticipated that the reliability of this new, updated version would also be quite high with high Intra-class Correlations (ICC’s) and narrow limits of agreement in the Bland and Altman calculations.

3.3 Methodology:

3.3.1 Study Design:
This study aimed to investigate the reliability of the second band of the MABC-2 with a population of 7-9 year old children. The study looked at a random sample of children which represented the general population of children in mainstream schools. A quantitative research approach was employed within this study with each child’s performance on the assessment documented and compared to standardised normative scores given the child’s age.
3.3.2 Ethical Approval:
Ethical approval was granted by the University of Limerick Research Ethics Committee prior to recruitment. The University of Limerick Child Protection Guidelines (2006) were adhered to at all times while conducting this study.

3.3.3 Participants:

3.3.3.1 Recruitment:
Second class pupils from mainstream primary schools in County Limerick were invited to partake in this reliability study. These participants represent a convenience sample and give a general representation of a normal paediatric population.

As part of the recruitment process for both studies in this project a list of 32 of primary schools in county limerick was retrieved from a government site. Irish speaking schools were excluded due to the lack of facilities to translate the assessments to Irish without reducing the stability of the tests.

Each school principal was sent a letter inviting the second class pupils within their school to participate in the study. 11 schools agreed to participate in the study and from this 2 schools were randomly chosen by an impartial external to make up the study sample for this reliability study.

Each pupil within second class aged 7-10 years was given information leaflets for parents (Appendix C), information leaflets for themselves (Appendix D) and a consent form (Appendix E) for both the parent/guardian and child. A total of 22 children were invited to partake in the study with 20 consenting to participation. The response rate was 91 percent. Informed written consent was obtained from each parent/guardian and child before participation was allowed (Figure 5). Each participant also met the necessary inclusion criteria essential to participate safely and effectively in this study (Table 8).
The participating children ranged from 7 years 11 months to 9 years 3 months (Mean=102.8 months ± SD 6.45). This sample was comprised of 12 boys and 8 girls (Table 7).

**Table 7: Demographics of the participants in the reliability study**

<table>
<thead>
<tr>
<th>School</th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>G</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>H</td>
<td>9</td>
<td>6</td>
</tr>
</tbody>
</table>
3.3.3.2 Inclusion/Exclusion Criteria:

Table 8: Inclusion and Exclusion Criteria for participation in the study

<table>
<thead>
<tr>
<th>Inclusion Criteria</th>
<th>Exclusion Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Participants were at least 7 years at the time of assessment to ensure they can be accurately assessed using the second band of the MABC-2.</td>
<td>1. Participants with difficulty understanding the English language were not be able to follow instructions of the manual correctly and will be excluded.</td>
</tr>
<tr>
<td>2. Participants were enrolled in mainstream Primary Schools in County Limerick for the academic year 2009/2010.</td>
<td>2. Children excluded from physical education within the school were excluded from this study.</td>
</tr>
<tr>
<td>3. Informed written consent was obtained from Parent(s)/Guardian(s) and the child.</td>
<td></td>
</tr>
<tr>
<td>4. Children had a level of cognitive development that allowed them to follow test instructions appropriately.</td>
<td></td>
</tr>
</tbody>
</table>

3.3.4 Outcome Measure:

The MABC-2 tests the motor competence of children aged 3-16 years and unlike the MAND, this test is divided into three age bands. These age bands are 3 to 6 years, 7 to ten years and 11 to 16 years. Within each age band, eight tasks are grouped under three headings: Manual Dexterity, Aiming & Catching and Balance. The second age band will be utilised in this reliability study, the eight tasks in this age band (Figure 6).
Figure 6: Tasks of the second age band of the MABC-2

For each item raw scores are collected for each of the eight tasks. These are totalled to create manual dexterity, ball skills and balance tasks and an overall Total Impairment Score. These raw scores are then converted to standard scores based on normative data for each year between 7 and 10 years. Age adjusted standard scores and percentiles are also provided for the 3 components of the MABC-2 and the total score. These standard scores and percentiles are then interpreted utilising a traffic light system to categorise children into a normal (green; Total Impairment Score > 67; > 15th Percentile), borderline (amber; Total Impairment Score 57-67; 5th – 15th Percentile) or motor impaired (red; Total Impairment Score ≤ 56; ≤5th Percentile) group (Henderson et al. 2007). The minimal and maximum score that each child can achieve when raw scores are converted to percentiles varies with age, however in general the lower total impairment score and lower percentile the poorer the motor proficiency of the child.

3.3.5 Procedure:
Children who consented to participate and subsequently met the inclusion and exclusion criteria were assessed using the MABC-2. These assessments were conducted in the spring term within the child’s normal school environment, maximising the ecological validity of the
assessments and ensuring the testing environment is similar to that of the main validation study.

The testing was conducted with children in groups of three also simulating the normal school environment where children sit in groups at desks within the dynamic classroom setting.

Children performed the manual dexterity items while sitting at their normal school desks that they use on a daily basis, thus maintaining the normal posture that they would adopt in the classroom on a daily basis.

The testing protocols and scoring were conducted using the exact procedure outlined in the MABC-2 handbook (Henderson et al. 2007) with minimal prompting incorporated into the testing. Each child's performance was documented on coded standardised assessment sheets throughout the testing procedure. Two experienced physiotherapists were present at all times during testing.

To obtain inter-rater reliability each group was assessed by one tester while the other tester observed and independently scored the child on each task within the MABC-2, a similar methodology to that of Chow and Henderson (2003). The first rater conducted all assessments with the second rater scoring the child’s performance independently.

To obtain the intra-rater reliability the first assessor repeated the assessments with a two week interval between the first and second administration of the MABC-2 (Chow et al. 2002). This interval was anticipated to be long enough to avoid a learning effect and prevent this form of systematic bias. To minimise changes in environmental factors which could affect the results, pupils were assessed the same weekday at the same time and in the same location on the separate occasions (Van Waelvelde et al. 2007b).

3.3.6 Data Analysis:
All analysis was conducted using Statistical Programme for Social Sciences (SPSS) version 16.0. Reliability is best estimated by more than one index (Bruton et al. 2000). Most recent literature suggests that the most appropriate statistical analysis for determining reliability is the intra-class correlation coefficient (ICC) on data produced from an analysis of variance (ANOVA) and the Bland and Altman method (Rankin and Stokes 1998). It is recommended that Bland and Altman calculations and ICC’s are combined to give a good indication of the
magnitude of disagreement between measurements within a clinical context (Rankin and Stokes 1998, Bruton et al. 2000).

### 3.3.6.1 ICCs

ICC’s and their 95% Confidence Intervals (CI’s) were calculated to show the level of association between measures obtained for standard scores of each of the eight components of the MABC-2, the standard scores of the 3 sub-categories and the Total Impairment Scores for each individual. ICC’s and their 95% confidence intervals (CI’s) for intra-rater and inter-rater reliability express numerically the magnitude and direction of the association between two variables. A value of 1 indicates perfect reliability and 0 indicates no reliability, while an ICC of >.75 suggests good reliability (Khan and Chien 2001, Portney and Watkins 2007). Table 9 demonstrates the rating of the reliability according to ICC coefficients as classified by Portney and Watkins in 2007.

**Table 9: Key of strength of Intra-class correlation coefficient (Portney and Watkins 2007)**

<table>
<thead>
<tr>
<th>Rating</th>
<th>Numerical Value of Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>$\geq 90$</td>
</tr>
<tr>
<td>Good</td>
<td>0.75-0.90</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.50-0.75</td>
</tr>
<tr>
<td>Poor</td>
<td>$&lt; 0.50$</td>
</tr>
</tbody>
</table>

When selecting the appropriate ICC, an important decision is whether the data will be treated utilising a one or two way ANOVA model. For this particular study in which both inter- and intra-rater reliability were being investigated both types of ANOVA had to be utilised. For determining the ICC for inter-rater reliability a two-way mixed model of ANOVA or ICC (3,1) was utilised. This was selected as testing was only performed by two raters and the study is being conducted to inform the larger validation study for the same raters (Rankin and Stokes 1998). Meanwhile, for investigating the intra-rater reliability of the measurements obtained on both occasions a one way random effects model or ICC (1,2) was the choice of analysis.
The 95% CIs were also calculated. This is the range of values that one is 95% confident that the ICC lies within (Pallant 2007, Bruton et al. 2000). Calculating the 95% CI of the ICC is necessary to reflect the precision of the estimate i.e. to indicate true reliability.

The advantages of ICCs are that inter-rater reliability can allow for fixed or random effects and the coefficient is simple to understand. The primary disadvantages of using ICCs are that they give no indication of actual measurement values or any bias in measurements, hence necessitate further analysis of absolute reliability (Bruton et al. 2000). Absolute reliability is the degree to which repeated measurements vary for individuals. Subsequently, ICCs should be complemented by Bland and Altman methods to increase the strength and clinical relevance of the reliability of the measurement (Rankin and Stokes 1998).

### 3.3.6.2 Bland and Altman Calculations

Bland and Altman calculations include three steps: calculating the mean, the standard deviation and the 95% confidence interval (CI) of the differences between the measures, plotting the mean difference in the two results against the mean value from the two results and calculating 95% limits of agreement (LOA) (Bruton et al. 2000). SPSS was used to calculate the first two steps of the Bland and Altman method and the 95% LoA were calculated manually.

The reliability of the measurement increases the closer to zero the mean difference is and the narrower the 95% CI for the mean difference are. The Standard Error of the mean difference is also included in these calculations as it is a measure of how good the estimate of the mean difference is. Again the closer to zero this figure is the more reliable the measurement is. Another component of the Bland and Altman calculations is the 95% limits of agreement. The 95% LoA are the range in which subjects’ results would be expected to fall in repeat administrations of a test and is important within this study as it can relate to the clinical acceptability of the reliability obtained for the MABC-2. However, the 95% limits of agreement within study had to be interpreted with caution as because the sample size is smaller than 50 the limits were likely to be very wide (Rankin and Stokes 1998).

Scatter plot diagrams were utilised to illustrate the distribution of results. These Bland and Altman plots are created by plotting the differences between two measures against the mean of the two measures. These graphs allow easy interpretation of the data visually, identifying
the size and range of differences in measurements, any bias or outliers, or relationship between the size of differences with the size of the mean (Rankin and Stokes 1998).

3.4 Results:

3.4.1 Inter-rater reliability

Both ICCs and Bland and Altman calculations were utilised to investigate inter-rater reliability. The ICC is important as it expresses the magnitude and direction of the association between the results of both raters. Meanwhile, the Bland and Altman calculations are important with this clinically administered measurement as they give vital information about the actual level of agreement between both raters. Each of these results is outlined in Table 10 below.
### 3.4.1.1 ICCs and Bland and Altman Calculations

**Table 10: ICCs and Bland and Altman calculations for Inter-rater Reliability**

<table>
<thead>
<tr>
<th>Task</th>
<th>ICC</th>
<th>95% CI</th>
<th>d</th>
<th>SE of d</th>
<th>95% CI of d</th>
<th>SD_{diff}</th>
<th>95% LoA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placing Pegs</td>
<td>.950</td>
<td>.877 → .980</td>
<td>-.60</td>
<td>.210</td>
<td>-1.04 → -.16</td>
<td>.940</td>
<td>-2.4424 → 1.2424</td>
</tr>
<tr>
<td>Threading Lace</td>
<td>.986</td>
<td>.964 → .994</td>
<td>.00</td>
<td>.103</td>
<td>-.21 → .21</td>
<td>.459</td>
<td>-.89964 → .89964</td>
</tr>
<tr>
<td>Drawing Trail</td>
<td>.884</td>
<td>.731 → .952</td>
<td>.25</td>
<td>.481</td>
<td>-.76 → 1.26</td>
<td>2.149</td>
<td>-3.96204 → 4.46204</td>
</tr>
<tr>
<td>Manual Dexterity</td>
<td>.903</td>
<td>.772 → .961</td>
<td>.00</td>
<td>.332</td>
<td>-.70 → .70</td>
<td>1.487</td>
<td>-2.91452 → 2.91452</td>
</tr>
<tr>
<td>Catching with Two Hands</td>
<td>.913</td>
<td>.794 → .965</td>
<td>.75</td>
<td>.315</td>
<td>-1.41 → -.09</td>
<td>1.410</td>
<td>-3.5136 → 2.0136</td>
</tr>
<tr>
<td>Throwing Beanbag onto Mat</td>
<td>.728</td>
<td>.431 → .883</td>
<td>.65</td>
<td>.514</td>
<td>-1.73 → .43</td>
<td>2.300</td>
<td>-5.158 → 3.858</td>
</tr>
<tr>
<td>Aiming and Catching</td>
<td>.895</td>
<td>.754 → .957</td>
<td>-1.00</td>
<td>.348</td>
<td>-1.73 → -.27</td>
<td>1.556</td>
<td>-4.04976 → 2.04976</td>
</tr>
<tr>
<td>1 Board Balance</td>
<td>.984</td>
<td>.960 → .994</td>
<td>-.15</td>
<td>.196</td>
<td>-.56 → .26</td>
<td>.875</td>
<td>-1.865 → 1.565</td>
</tr>
<tr>
<td>Walking Heel-Toe Forwards</td>
<td>.970</td>
<td>.925 → .988</td>
<td>.20</td>
<td>.200</td>
<td>-.22 → .62</td>
<td>.894</td>
<td>-1.55224 → 1.95224</td>
</tr>
<tr>
<td>Hopping on Mats</td>
<td>.458</td>
<td>.032 → .744</td>
<td>.60</td>
<td>1.180</td>
<td>-1.87 → 3.07</td>
<td>5.276</td>
<td>-9.74096 → 10.94096</td>
</tr>
<tr>
<td>Balance</td>
<td>.807</td>
<td>.575 → .919</td>
<td>.20</td>
<td>.511</td>
<td>-.87 → 1.27</td>
<td>2.285</td>
<td>-4.2786 → 4.6786</td>
</tr>
<tr>
<td>Total Impairment Score</td>
<td>.971</td>
<td>.928 → .988</td>
<td>-1.10</td>
<td>.876</td>
<td>-2.93 → .73</td>
<td>3.919</td>
<td>-8.78124 → 6.58124</td>
</tr>
</tbody>
</table>

**Note:** ICC = Intraclass correlation co-efficient; 95% CI=95% Confidence Interval; d= mean difference; SE of d= Standard Error of the mean difference; 95% CI of d is= 95% confidence interval for the mean difference; SD_{diff} = Standard Deviation of the mean differences, and 95% LoA= 95% limits of agreement of the mean differences.
3.4.1.1 ICCs

The ICC for the Total Impairment Score was .971 which is greater than the 0.90 level that is indicative of excellent reliability (Bruton et al. 2000). The Manual Dexterity, Aiming and Catching and Balance components of the MABC-2 are also reliable, with ICCs of .903, .895 and .807, respectively. These are all substantially above the level 0.75 which is deemed as good reliability (Khan and Chien 2001, Portney and Watkins 2007).

At a more in-depth level the ICCs of each of the eight tasks was also investigated. Six of the eight of these tasks were above the ICC = 0.75 level indicating good inter-rater reliability. The throwing the beanbag onto the mat and the hopping on mats tasks were below this level with ICC’s of .728 and .458, demonstrating moderate and poor reliability, respectively.

The next analysis used to show the level of association between measurements of both raters was the 95% confidence interval range. Firstly, the overall reliability of the MABC-2 as represented by the TIS has a narrow range (.928 → .988). This conveys good reliability, as the ICC value is present within a very limited set of values.

Upon investigating the 3 subgroups of the MABC-2 it is evident that the 95% CI is also relatively narrow for each of the groups, with Manual Dexterity having the narrowest range (.772 → .961).

The 95% CI’s varied between the eight individual tasks of the MABC-2, however most of these too had quite a narrow range in which one can be 95% confident that the ICC lies within (Table 8).

3.4.1.1.2 Bland and Altman Calculations

When looking at the Bland and Altman Calculations for the relationship between the TIS of both raters most of the findings indicate that there is a good absolute inter-rater reliability. This is determined due to the mean and standard error of the mean being close to zero (relative to raw data measurements), -1.10 and .876, respectively. Initially it seemed that the 95% LoA for the difference between the measurements were quite narrow ranging from -8.78124 → 6.58124 given that Total Impairment Scores can go as high as 120. However, when put in clinical context caution must be paid as there is only a change of 12 necessary for
a child to move from the non-motor impaired to the motor impaired category. The possible reasoning for these broad 95% Limits of Agreement is outlined in the discussion chapter.

The 95% CI for the mean passes through zero which indicates that no bias occurred between the measurements of raters. This is also reflected in Figure 7 as the differences between the scores obtained between each rater are distributed above and below zero.

Similar to the ICC calculations, the Bland and Altman calculations of the manual dexterity subgroup was higher than that of the Aiming and Catching and Balance Subgroups. The mean difference of the Manual Dexterity component indicated perfect agreement (.00) while the Standard Error of the Mean was also quite small (.332). The 95% CI for the mean difference passed through zero (-.70 → .70) indicating that no bias occurred. This is also illustrated in figure 6 with points evenly distributed above and below zero. The 95% LoA for the manual dexterity component of the MABC-2 were also quite narrow (-2.91452 → 2.91452). However, similar to the TIS, interpreted clinically this difference of 6 could potentially move a child from one category of motor abilities to another.

The Balance component of the MABC-2 was found also to have good agreement between raters. The mean difference and standard error of the mean difference are very small, .20 and .511, respectively. The 95% CI for the mean difference was narrow, passing through the zero (-.87 → 1.27) indicating that no bias occurred between raters.

The aiming and catching component had a higher mean difference between raters (-1.00) indicating lower inter-rater reliability. The 95% CI for the mean difference is -1.73 → -.27. Zero does not lie within the interval which indicates a bias between the two measurements. Figure 9 also illustrates this bias with all but two points below zero, i.e. the differences (rater 1- rater 2) have a negative value. Therefore, 18 of the measurements taken by the second rater were larger than those taken by the first rater.

The 95% LoA of the Aiming & Catching and Balance components were wider denoting poorer absolute reliability when clinically interpreted.
Figure 7: Scatterplot from Bland and Altman test for inter-rater reliability of the TIS between tester 1 and tester 2.

Figure 8: Scatterplot from Bland and Altman test for inter-rater reliability of the Manual Dexterity Component of the MABC-2 for tester 1 and tester 2.

<table>
<thead>
<tr>
<th>________________</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>-----------------</td>
<td>-----------------</td>
</tr>
</tbody>
</table>

95% Limits of Agreement
Figure 9: Scatterplot from Bland and Altman test for inter-rater reliability of the Aiming and Catching Component of the MABC-2 between tester 1 and tester 2.

Figure 10: Scatterplot from Bland and Altman test for inter-rater reliability of the Balance Component of the MABC-2 between tester 1 and tester 2.

*Note: Scales in figures 7-10 are varied due to the difference in the optimal scores that can be achieved on each component of the MABC-2 versus the TIS
The distribution of scatter plots in Figures 7-10 illustrate the relationship between the results obtained between testers as calculated utilising Bland and Altman methods. It is illustrated that all data points are within the 95% limits of agreement for Aiming and Catching. Within the TIS and Manual Dexterity components, it is worth noting that the two outliers within each of these assessments are quite close to the upper and lower 95% LoA and are not substantial. Given that the majority of differences between tester 1 and tester 2 are found within the 95% limits of agreement for all four components of the MABC-2, reasonably good absolute reliability is indicated.

Also worth noting within the scatterplots, all except for Figure 10, balance, show a good distribution of points above and below zero, rater bias did not occur in these three areas.

3.4.2 Intra-rater Reliability

ICCs and Bland and Altman calculations were also used to investigate the relative and absolute inter-rater reliability of the MABC-2 (See Table 11).
### 3.4.2.1 ICCs and Bland and Altman Calculations:

Table 11: ICCs and Bland and Altman calculations for Intra-rater Reliability

<table>
<thead>
<tr>
<th>Task</th>
<th>ICC</th>
<th>95% CI</th>
<th>D</th>
<th>SE of d</th>
<th>95% CI of d</th>
<th>SD (<em>{d</em>{iff}})</th>
<th>95% LoA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placing Pegs</td>
<td>.268</td>
<td>-.177→.626</td>
<td>.40</td>
<td>.884</td>
<td>-1.45→2.25</td>
<td>3.952</td>
<td>-7.34592→8.14592</td>
</tr>
<tr>
<td>Threading Lace</td>
<td>.349</td>
<td>-.090→.677</td>
<td>-1.25</td>
<td>.615</td>
<td>-2.54→0.04</td>
<td>2.751</td>
<td>-6.64196→4.14196</td>
</tr>
<tr>
<td>Drawing Trail</td>
<td>.390</td>
<td>-.042→.702</td>
<td>.45</td>
<td>1.077</td>
<td>-1.80→2.70</td>
<td>4.817</td>
<td>-8.99132→9.89132</td>
</tr>
<tr>
<td>Manual Dexterity</td>
<td>.751</td>
<td>.479→.893</td>
<td>-.20</td>
<td>.546</td>
<td>-1.34→.94</td>
<td>2.441</td>
<td>-4.98436→4.58436</td>
</tr>
<tr>
<td>Catching with 2 Hands</td>
<td>.437</td>
<td>.014→.730</td>
<td>-.95</td>
<td>.809</td>
<td>-2.64→.74</td>
<td>3.620</td>
<td>-8.0452→6.1452</td>
</tr>
<tr>
<td>Throwing Beanbag onto Mat</td>
<td>.645</td>
<td>.302→.841</td>
<td>.15</td>
<td>.612</td>
<td>-1.13→1.43</td>
<td>2.739</td>
<td>-5.21844→5.51844</td>
</tr>
<tr>
<td>Aiming and Catching</td>
<td>.620</td>
<td>.264→.829</td>
<td>-.45</td>
<td>.690</td>
<td>-1.89→.99</td>
<td>3.086</td>
<td>-6.49856→5.59856</td>
</tr>
<tr>
<td>1 Board Balance</td>
<td>.444</td>
<td>.023→.734</td>
<td>-1.75</td>
<td>1.326</td>
<td>-4.52→1.02</td>
<td>5.928</td>
<td>-13.36888→9.86888</td>
</tr>
<tr>
<td>Walking Heel-Toe Forwards</td>
<td>.500</td>
<td>.094→.765</td>
<td>.50</td>
<td>.863</td>
<td>-1.31→2.31</td>
<td>3.859</td>
<td>-7.06364→8.06364</td>
</tr>
<tr>
<td>Hopping on Mats</td>
<td>.212</td>
<td>-.234→.589</td>
<td>-2.20</td>
<td>.922</td>
<td>-4.13→.27</td>
<td>4.124</td>
<td>-10.28304→5.88304</td>
</tr>
<tr>
<td>Balance</td>
<td>.775</td>
<td>.521→.904</td>
<td>-.35</td>
<td>.539</td>
<td>-1.48→.78</td>
<td>2.412</td>
<td>-5.07752→4.37752</td>
</tr>
<tr>
<td>Total Impairment Score</td>
<td>.732</td>
<td>.446→.884</td>
<td>4.65</td>
<td>2.793</td>
<td>-2.93→.73</td>
<td>12.491</td>
<td>-29.13236→19.83236</td>
</tr>
</tbody>
</table>

**Note:** ICC= Intraclass correlation co-efficient; 95% CI=95% Confidence Interval; \(d\)= mean difference; SE of \(d\)= Standard Error of the mean difference; 95% CI of \(d\) is= 95% confidence interval for the mean difference; \(SD_{diff}\) = Standard Deviation of the mean differences, and 95% LoA= 95% limits of agreement of the mean differences.
The ICC for the Total Impairment score was ICC = .732, denoting moderate intra-rater reliability (Portney and Watkins 2007, Bruton et al. 2000). The Manual Dexterity, Aiming and Catching and Balance components of the MABC-2 were found to have moderate to good intra-rater reliability, ICCs are .751, .620 and .775, respectively. The manual dexterity and balance components were above the level ICC = 0.75 which is deemed as good reliability (Khan and Chien 2001). However, the Aiming and Catching component only demonstrated moderate intra-rater reliability.

To determine the intra-rater reliability of the MABC-2 comprehensively ICC values of each of the eight tasks was also investigated. The intra-rater reliability of the tasks ranged from poor to moderate (Table 11).

Subsequent to this the level of association between measurements obtained by rater one on both occasions was investigated through the 95% confidence interval range. The overall reliability of the MABC-2 as represented by the TIS had quite a broad range (.446 → .884). This conveys moderate reliability, with the ICC expected to lie within quite a broad range of values.

The 95% CI were also investigated for the 3 components of the MABC-2. Similar to the ICC values, the Manual Dexterity and Balance components demonstrated their good reliability with narrower intervals than the aiming and catching component which was quite broad (264→ .829).

The 95% CI for each of the eight tasks within the MABC-2 were all quite broad denoting poor intra-rater reliability at an individualised level (Table 9).

**3.4.2.1.2 Bland and Altman Calculations**

Bland and Altman calculations found the MABC-2 to also have acceptable absolute intra-rater reliability initially when looking at the mean difference, however upon investigating the range in the 95% Limits of Agreement calculations the stability of the results obtained on the separate days is questionable. The overall TIS illustrated moderate reliability with the mean difference and the standard error of the mean quite small relative to the overall scale for Total Impairment Score scale (0-120), 4.65 and 2.793 respectively. However, the 95% LoA for the difference between the measurements were quite broad -29.13235 → 19.83236, considering
that a child can move from the non-motor impaired to motor impaired category with a change of 16. This subsequently reduces the clinical relevance of the intra-rater reliability. Once again the likely reasoning for this will be addressed in the discussion section.

The 95% CI for the mean passes through zero indicating that no bias occurred between the measurements taken on day one versus day two. This is also reflected in Figure 11 with the differences between the scores obtained on both occasions distributed above and below zero.

The Bland and Altman calculations reflected the ICC calculations with the manual dexterity and Balance subgroups demonstrating higher repeatability than the aiming and catching subgroup. The mean difference of the Manual Dexterity component indicated very good agreement between measurement with a very small $d$ and SE of $d$, -.20 and .546, respectively. The $d$ and SE of $d$ of the balance component were also small (-.35 and .539), indicating good repeatability between measurements. The aiming and catching component demonstrated poorer repeatability over the two occasions with a higher $d$ and SE of $d$ (-.45 and .690).

The 95% CI for the mean difference passed through zero for each of the three components indicating that no bias occurred. This is also illustrated in figures 12-14 with points evenly distributed above and below zero. The 95% LoA varied between the three components, with the manual dexterity and balance components having narrower limits of agreement, denoting higher intra-rater reliability for these components of the MABC-2 than the aiming and catching component (Table 11).
Figure 11: Scatterplot from Bland and Altman test for intra-rater reliability of the TIS between Day 1 and Day 2.

Figure 12: Scatterplot from Bland and Altman test for intra-rater reliability of the MABC-2 Manual Dexterity Scores between Day 1 and Day 2.
Figure 13: Scatterplot from Bland and Altman test for intra-rater reliability of the MABC-2 Aiming and Catching Scores between Day 1 and Day 2.

Figure 14: Scatterplot from Bland and Altman test for intra-rater reliability of the MABC-2 Balance Scores between Day 1 and Day 2.

*Note: Scales in figures 7-10 are varied due to the difference in the optimal scores that can be achieved on each component of the MABC-2 versus the TIS*
The distribution of scatterplots in Figures 11-14 illustrate the relationship between the results obtained by one rater on two separate occasions as calculated utilising Bland and Altman methods. It is illustrated that all data points are within the 95% limits of agreement for the Manual Dexterity component. Within the TIS, aiming & catching and balance components, it is worth noting that the one or two outliers within each of these scatterplots are quite close to the upper and lower 95% LoA and are not substantial. The majority of differences between measurements obtained on day one versus day two are found within the 95% limits of agreement for all four components of the MABC-2, however given that the 95% LoA are relatively broad, only reasonably good absolute reliability is indicated.

3.5 Discussion:

“The reliability of a scale can vary depending on the sample with which it is used” (Pallant 2007). This statement was pertinent within the current research due to the specific population with which the second band of the MABC-2 was to be administered. At the time this research was being conducted there was a paucity of evidence surrounding the reliability of the revised version of the MABC-2. Of particular importance was that there had been no studies investigate the reliability of the second band of the MABC-2. The current study aimed to fill this gap in the literature and investigate the inter- and intra-rater reliability of the MABC-2 with 7-9 year old children attending mainstream primary schools.

An important aspect of the MABC-2 is its ability to examine the motor competence of the child in three specific and individual areas; Manual Dexterity, Aiming & Catching and Balance (Henderson et al. 2007). Subsequently, the reliability of the TIS of the child, along with these components and the individual 8 tasks that comprise that MABC-2 were each investigated.

The hypothesis of this study was that both the inter- and intra-rater reliability of the second band of the MABC-2 would be high. This would be anticipated as previous studies of the original MABC demonstrated good reliability. Studies that investigated the reliability of the first and third age bands of the revised version of the MABC-2 also demonstrated good reliability. Upon considering the results of previous studies, it would be expected that the reliability of the components and the tasks of the MAND would be poorer than the TIS.
Both relative and absolute inter-rater reliability of the TIS of the MABC-2 was found to be excellent. This relative inter-rater reliability was determined by the high ICC (ICC = 0.97) and narrow 95% CI (.928 →.988). This ICC was higher than the only inter-rater reliability studies of the MABC-2 utilising age band three. The TIS ICC for these studies were 0.94 and 0.79 indicating good to excellent reliability (Chow et al. 2002, Faber and Nijhuis van der Sanden 2004). A high ICC for TIS was also found in the original MABC (Van Waelvelde et al. 2007b, Chow and Henderson 2003).

Looking closer at the components of the second age band of MABC-2, Manual Dexterity was found to have the highest reliability (ICC = .903), followed by Aiming & Catching (ICC = .895) and Balance (ICC = .807). Manual Dexterity and Aiming & Catching had a narrow 95% CI, however Balance had a wider 95% CI, indicative of lower reliability. The Ball skill component in this current study was much higher than that achieved by Van Waelvelde et al. (2007), ICC 0.45. However, the Van Waelvelde study was investigating the reliability of the first age band of the original MABC with younger children who would not be as proficient in Ball Skills as 7 year old children (Malina 2004).

An advantage of this study over previous reliability studies is that it utilised Bland and Altman Calculations to determine absolute inter- and intra-rater reliability. As can be seen in the results section, when the 95% LoA are applied in a clinical context the findings demonstrated poorer reliability for the TIS and the 3 components of the MABC-2. These results did not complement the findings of the ICC calculations which found the TIS to have excellent inter-rater reliability. Even within the Bland and Altman calculations, the Manual Dexterity component which was found to have excellent absolute inter-rater reliability with a mean difference of .00, representing perfect agreement had relatively wide 95% LoA -2.91452 → 2.91452. This indicates that a possible cause for these broad 95% LoA could be the small sample size less than 50 which has been indicated as a cause for having wider 95% LoA (Rankin and Stokes 1998). Hence, these limits of agreement could be inaccurate indicators of the reliability of the MABC-2 given the excellent ICC values and small mean differences obtained for TIS and the three components of the MABC-2.

To investigate the reliability of the MABC-2 comprehensively it was necessary to look closely at each of the eight tasks that comprise the second age band. The reliability of the eight individual tests varies from poor to excellent (ICC .458 → .986). Five of the eight tests demonstrated excellent inter-rater reliability, meanwhile the Drawing Trail had good
reliability (ICC = .884), the throwing beanbag onto the mat task had moderate reliability (ICC = .728) and the hopping on mats task demonstrated the poorest reliability (ICC = .458). These ICCs were similar to those achieved in a study that investigated the reliability of a provisional age band four of the MABC-2 with most tasks having excellent reliability (ICC = 0.92-1.00) (Chow et al. 2002). Similar to this current study the eight task, jumping and clapping, too demonstrated lowest reliability (ICC = 0.52).

The eight task in the second age band requires the child to hop consecutively along six mats landing in a static position on a circle within the target mat. While performing this task the child must maintain their balance and may not hop on the boundaries of the mat. Each consecutive hop is counted with a maximum of 5 hops being performed. The reasoning for the low reliability of this task could be the difficulty for the examiner in analysing all aspects of the task together to ensure the correct amount of mats are being counted without any mistakes being made by the child. This is especially difficult due to the speed at which the child can perform this task in a continuous sequence without being allowed to pause between each hop (Henderson et al. 2007). Also, due to the low range in which the child can score as a raw score (0-5), a single error on the part of the examiner can lead to a large discrepancy between when this data is transformed into scaled scores in this task.

The only task that demonstrated poor reliability was the second aiming and catching task; throwing a beanbag onto mat. Within this task the child must stand on one mat and throw the beanbag 1.8 metres to the target mat. The child has five practice attempts and 10 formal trials within this task (Henderson et al. 2007). However, there are numerous things for the examiner to observe from the initial throw to the landing of the beanbag. Consequently, similar to the hopping trial, due to the speed at which the throw is performed it is sometimes difficult to quickly analyse positioning of the beanbag as it is quickly thrown onto the mat and can quickly touch a boundary of the target before quickly sliding off. This may be seen by one examiner and not by another depending on their positioning relative to the target mat.

Although the intra-rater reliability of the second age band of the MABC-2 was poorer than that of the inter-rater reliability the TIS and 3 components were found to have acceptable levels of reliability ranging from moderate to good when looking purely at ICCs and relative reliability. This higher inter-rater reliability than intra-rater reliability is similar to findings within a reliability study of the original MABC (Chow and Henderson 2003) and to a reliability study of the third age band of the revised MABC-2 (Chow et al. 2002).
Firstly, the intra-rater reliability of TIS was found to have moderate relative and absolute reliability. Moderate relative inter-rater reliability was determined by the moderate ICC (ICC = .732). This ICC is similar to that obtained in a reliability study age band three. The TIS ICCs for these studies were 0.62→0.92 and 0.79 indicating moderate to good reliability (Chow et al. 2002, Faber and Nijhuis van der Sanden 2004). However, it is worth noting that the children within these studies were older and subsequently were likely to have more proficient and consistent motor skills. When comparing TIS within this study to studies investigating reliability of the original MABC with children of similar ages a similar value (ICC = 0.77) was obtained (Chow and Henderson 2003).

Two components of the second age band of MABC-2, Balance (ICC = .775) and Manual Dexterity (ICC = .751) were found to have good relative intra-rater reliability. Meanwhile, Aiming & Catching had lower reliability (ICC = .620), signifying moderate consistency between measurements obtained on the two occasions with these tasks. This finding is consistent with the findings of Visser et al. (2004) who found the aiming and catching component of the first band of the MABC-2 to have the poorest test-retest reliability (ICC = 0.49).

Similar to the inter-rater reliability, the Bland and Altman calculations demonstrated poorer absolute intra-rater reliability when the 95% LoA were investigated and put in a clinical context. Aspects of the Bland and Altman calculations supported the findings of the ICC coefficients and indicated that the three components of the MABC-2 have moderate reliability (Bland and Altman 1986). However, upon analysing the 95% LoA these results were slightly contradicted due to the relatively broad 95% LoA. Again, due to the inconsistencies between the ICC values, mean difference values and the 95% LoA, it could be concluded that the reasoning for the broad 95% LoA is the small sample size in the current study.

The Bland and Altman plots illustrated the even distribution between the differences of the measurements on both days above and below zero, visually implying that no bias occurred between the measurements collected on day one versus day 2.

Detailed analyses of the eight tasks that comprise the second age band of the MABC-2 indicate that the intra-rater reliability of each of these components is poor to moderate (Table 11). Hence, these individual tasks should not be administered to a child as an individual
measurement and should be complemented and strengthened by administering with the other tasks within each of the three components.

These reliability studies used two methods of statistical analysis; ICCs and Bland and Altman calculations; to investigate the inter- and intra-rater reliability of the MABC-2. Although the ICCs revealed moderate and high correlations for intra-rater and inter-rater reliability, respectively; relatively broad 95% LoA contradicted this. These relatively broad 95% LoA reduce the clinical significance of the findings. However, although given these broad 95% LoA it may appear that the reliability of the MABC-2 within a clinical context is poor it is worth noting that a reasoning for this has been outlined (Rankin and Stokes 1998). This states that in a study with a sample size smaller than 50 the limits will be very wide.

Consequently, to conclude one could assume that given the relatively high ICCs and the small mean difference scores obtained through Bland and Altman calculations, the MABC-2 does have good inter-rater and moderate intra-rater reliability and it is the small sample size that has attributed to the broad 95% LoA that were achieved throughout the statistical analysis.

3.5.1 Limitations

The present study was not without limitations; consequently the results should be interpreted with caution.

The primary methodological limitation as has been addressed in the discussion chapter is the small sample size (n=20). When conducting Bland and Altman calculations this resulted in a broad range for 95% LoA which did not reflect the other statistical findings both within the ICC calculations and the other Bland and Altman calculations of mean and differences. Also, this small sample size decreases the study’s external validity, particularly given the homogeneity of the sample in question. This current study only investigated the reliability of the second age band of the MABC-2, consequently, the results may not be generalised to other age bands or age groups of children.

Another methodological flaw was that two children with attention deficits were included in this study, consequently, due to the probable inconsistencies in their motor performance due
to their reduced attention capacity the consistencies on the measurements could have been skewed. It has been proven that individuals with attention deficit to have increased variability in assessments that require speed and accuracy (Piek et al. 2004).

A limitation when looking at the sample is all of the children who participated in this study were attending mainstream primary schools, consequently, they were less likely to have a motor impairment making it likely for the test to have higher discrimination accuracy. However, this relatively healthy population needed to be investigated for the purpose of the validation study, as it was children aged 7-9 in mainstream primary schools with whom the validation study would be conducted.

3.6 Conclusion:

The present study is the first in the literature to investigate both inter- and intra-rater reliability of the second age band of the MABC-2. It focused on major ethos within the ICF regarding the importance of looking at the motor competence of a developing child within their regular daily environment i.e. school (Simeonsson et al. 2003). Although both inter- and intra-rater reliability were acceptable, ranging from moderate to excellent when 95\% LoA are excluded, exclusion of these reduces the clinical significance of the findings (Portney and Watkins 2007). Another important finding within this study is that TIS and the three components (Manual Dexterity, Aiming and Catching and Balance) are reliable when administered together, however the eight individual tasks lack reliability and should not be administered individually.

The reliability of the second band of the MABC-2, as determined within this study, makes it suitable to be administered within the larger validation study with a population of 7-9 year old children attending mainstream primary schools.
Chapter 4: The convergent validity of the MABC-2 and the MAND in an ecologically valid environment.

4.1 Introduction

As highlighted throughout the review, developmental motor delay is a growing concern particularly within the school environment. With its prevalence within this population so high it is important that a formal standardised motor test is implemented within this environment to detect these motor deficits. However, to date there are numerous assessment tools available for this purpose with varying psychometric and assessment properties, consequently there is still large uncertainty surrounding which tests to use. Subsequently, the aim of this study is to evaluate two tests, the MABC and the MAND, both of which are currently used with this school aged population. The primary psychometric property that shall be investigated is the construct validity of these assessment tools within mainstream school populations. It is crucial that assessments measure correctly what they are supposed to, a way of establishing this is through investigation of the convergent validity of two assessments. Through implementing and evaluating these tests in the same environment on the same occasion it would be anticipated that they should both identify the same children as having motor impairments and also identify similar motor competencies for each individual.

The primary aim of this study was to investigate the convergent validity between the MABC and the MAND within mainstream schools, incorporating an ecologically valid environment. This was investigated through examining the correlation between total scores along with factor and subtest scores of the MAND and the MABC-2, respectively.

4.1.1 What is Validity?

This quality of investigating the similarity between these tests and the components of these tests may be described as an aspect of validity. Validity may be defined as ‘the degree to which theory and evidence support the interpretation of a test’s scores in relation to the stated aims of the test’ (Henderson et al. 2007). The traditional concept of validity comprised of three separate components- content, criterion and construct validity, however Messick (1995) proposed a new concept of validity uniting these subgroups. This aspect of validity supports evidence of convergent and discriminant validity gathered from multi-method comparisons i.e. similar assessments. Subsequently, within this study, convergent patterns between the two motor assessments will be important indicating a correspondence between measures of a
similar construct (Messick 1995). Convergent validity may be described as a correspondence between measures of the same construct (Van Waelvelde et al. 2007a).

A further aspect of validity which is crucial, particularly when investigating the efficiency of assessments is ecological validity which focuses on the abilities of the child within their regular environment. Hence, it is of utmost importance that this is captured within these motor assessments. A way of incorporating this form of validity is through conducting the assessments within an ecologically valid environment i.e. school, and simulating the normal classroom and playground environment for various tasks of the MAND and the MABC-2.

4.1.2 Validation studies of MAND, MABC and MABC-2

Previous studies have investigated various aspects of validity of the MAND, the original MABC and the recently released revised version of the MABC, the MABC-2. The methodology and findings of these studies are outlined in table 10-13 below. Within these tables validation studies are divided into those that investigated the relationship between broad based tests such as the MAND and the original MABC (Brantner et al. 2009) and into studies that investigated the relationship between broad based tests and narrow based tests including tasks of the Korperkoordinations Test fur Kinder (Van Waelvelde et al. 2004).

A further study investigating the ecological validity of the MAND was conducted on 19 4 to 12 year old children within a mainstream primary school (Connell 2010). Within this study children were assessed by two researchers, independent of each other over two consecutive days. The same researcher conducted the assessments on the child individually and in groups to optimise reproducibility. Children were randomly assigned to groups of three by an impartial external to prevent selection bias. Children were assessed in groups of three on day one and individually on day two. ICCs were conducted to determine the reproducibility and subsequently the ecological validity of the MAND. NDI scores for children were good (ICC = .79) while the ICCs of the factors of the MAND ranged from moderate to excellent. Bimanual dexterity demonstrated poorest reproducibility (ICC = .67) while muscle power remained consistent on both occasions (ICC = .91).
Table 12: Validation Studies of the MAND

<table>
<thead>
<tr>
<th>Study</th>
<th>Assessment</th>
<th>Population/Sample</th>
<th>Testing Procedure</th>
<th>Validated Against</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tan et al. (2001)</td>
<td>MAND</td>
<td>Convenience sample 69 children aged 5-11 years (32 referred for intervention and 37 healthy controls)</td>
<td>Setting not specified. Administered by trained independent assessor; MAND day 1, second assessment same day and final assessment 2-33 days apart.</td>
<td>MABC</td>
<td>High concurrent validity between performance rankings for MI and non-MI for MAND/BOTMP ($r = 0.86$), MABC/BOTMOP ($r = 0.84$), and MABC/MAND ($r = 0.88$). MAND had higher sensitivity than the BOTMP; 81% versus 31%. BOTMP had a higher specificity than the MAND, 100% versus 92%. Positive predictive value MAND/MABC 91% and negative predictive value 83%. Overall, MAND is a more valid test for identification of MI in Australian children.</td>
</tr>
<tr>
<td>Brantner et al (2009)</td>
<td>MAND</td>
<td>118 healthy children aged 4-6 years.</td>
<td>Individually assessment by trained assessors with one week interval.</td>
<td>MABC</td>
<td>Considerable independence between the MAND and the MABC (65% variance unaccounted for). Limited agreement in classification of children with DCD (51%). Inconsistent discrimination accuracy (sensitivity 72%, specificity 80%, positive predictive value 63%, and negative predictive value 15%) of the MAND.</td>
</tr>
</tbody>
</table>
4.1.2.1 Validity of the MAND

A primary limitation of the MAND is the paucity of evidence surrounding the psychometric properties, including validity, of the assessment. This is disappointing given the usefulness of the MAND as a comprehensive measure of gross, fine and overall motor competence (McCarron 1982). Also, the MAND is one of the few tests that has a standardised set of ten tasks that are common for all age brackets from 3.5-18 years, enhancing the reliability of changing scores over time and inter-age comparison (Wilson 2005).

The limited studies investigating the MAND (Table 12) are surprising given the positive findings of the first popular study that investigated the concurrent validity of the MAND versus the popular BOTMP, using the MABC as the criterion measure (Tan et al. 2001). The study found the MAND to have a higher concurrent validity with the MABC ($r = 0.88$) than the BOTMP ($r = 0.84$). Another positive attribute of the MAND within this study was it was found to have a much higher sensitivity than the BOTMP, 81% versus 31%, respectively. This is important as it highlights the usefulness and accuracy of the MAND in identifying children with a motor impairment. This study concluded that the MAND was a more valid test than the BOTMP for identification of children with motor impairments. However, the findings of the study should be interpreted with caution due to the following methodological limitations:

- Convenience sample of 69 children recruited for the study, reducing external validity of findings.

- Administration of the assessments varied greatly with either the MAND or the BOTMP being administered the same day as the MABC and the second test being administered 2-33 days apart. This would influence the variability of the child’s performance according to the time of the day and day of week (Van Waalvelde et al. 2007b).

The second study found slightly contradicting results (Brantner et al. 2009). Although there was a statistically significant correlation between both assessments ($r = -.590$), a considerable degree of independence was found between both assessments (65%). The agreement between both assessments was also found to be relatively limited, with 77% overall agreement and only 51% consistency in identification of children with motor impairment. The sensitivity and specificity of the MAND were also found to be lower than those of Tan et al (2001), 72%
and 80%, respectively. Small to medium cross-correlations between components of the MAND and the MABC also indicate that the tests are essentially assessing different things. Brantner admitted that a reasonable explanation for this could be that the MABC was designed for diagnostic purposes to measure only the lower range of motor ability, whereas the MAND was designed to assess motor proficiency of a broader spectrum of motor ability within a general population (Brantner et al. 2009).

When interpreting the findings of Brantner’s study, it must be remembered that only the first age band of the original MABC was investigated, and this can not be generalised to other age bands. Also, given that the second age band will include children with more established motor proficiency than 4-6 year old children more stable performances in each of the tests would be anticipated (Malina 2004). Finally, the MABC-2 differs from the MABC as it is based on normative data and gives standard scores for the full range of motor abilities. This implies that similar to the MAND the MABC-2 provides information for a broad range of motor competencies; hence a higher convergent validity would be anticipated between the MAND and the revised MABC-2.
### 4.1.2.2 Validation studies of the MABC

#### Table 13: Validation studies of the MABC

<table>
<thead>
<tr>
<th>Study</th>
<th>Assessment</th>
<th>Population/Sample</th>
<th>Testing Procedure</th>
<th>Validated Against</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Correlation with Broad Based Assessments</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Croce et al. (2001)</em></td>
<td>MABC</td>
<td>106 Children 5-6 yr. (n: 20), 7-8 yr. (n: 20), 9-10 yr. (n: 46), and 11-12 yr. (n: 20).</td>
<td>Tested individually on an open area. Order of administration of two tests counterbalanced</td>
<td>BOTMP-LF BOTMP-SF</td>
<td>The concurrent validity of the BOTMP-LF ($r = 0.76$) and BOTMP-SF ($r = 0.71$), $p&lt;0.001$. These results support the use of the MABC as a measure of motor ability in children aged 5 to 12 years.</td>
</tr>
</tbody>
</table>
| *Van Waelvelde et al. (2007)* | MABC       | 31 4 children with some developmental disabilities 4 and 5 years. | Tested individually in a quiet room on the same day. Order of administration counterbalanced | Peabody Developmental Motor Scales-2 (PDMS-2) | Spearman Correlation Coefficient for Convergent Validity of  
- Total scores ($r = 0.76$).  
- Gross motor sub-scores ($r = 0.71$)  
- Fine motor sub-scores ($r = 0.48$).  
Low agreement between tests in identifying children with motor impairment (Kappa Statistic |
Although both assessments measure similar constructs, tests are not interchangeable.

### Correlation of MABC with narrow based assessments

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample Description</th>
<th>Methods</th>
<th>Results</th>
</tr>
</thead>
</table>
| Smits-Engelsman et al. (1998)                 | MABC               | 208 children 5-13 years (134 non-referred and 74 referred to Physical Therapists suspected of having a Motor Impairment) | Children tested by same Physiotherapist. Counterbalance order of administration. Korperkoodinatios Test fur Kinder (KTK) | Pearson’s correlation coefficient between total test performances of:  
  - non-referred group (r = 0.62, p<0.0001; 38% of shared variance)  
  - referred group: (r = 0.65, p<0.0001).  
  Although there was some variance in agreement between the detection of MI in both assessments, the degree of concordance between the tests were statistically significant. |
| Van Waelvelde et al. (2004)                   | MABC ball catching test and 2 dynamic balance test | 133 children 7-9 years. Individually assessed in a quiet room in a rehab centre or school. Order of assessment the same. | KTK beam and KTK jump | Correlation between ball catching test, dynamic balance test (KTK beam and KTK jump) and corresponding aspects of MABC varied from non-significant to highly significant (r = -0.74). Some items within the MABC had a ceiling effect and lack of discriminative power (change jumping in squares & walking tip-toe on line in 2nd age band.) |
Validation studies of the MABC outlined in table 13 were conducted against broad based tests (investigating relationships between overall motor performances) and narrow based tests (identifying ability of specific components of the MABC to measure the motor skills they aim to investigate).

A large positive correlation was found between the MABC and the BOTMP-LF ($r = 0.76$) and BOTMP-SF ($r = 0.71$) (Croce et al. 2001). Although these are strong correlations, agreement between the assessments in identifying children with motor impairments, the primary function of these assessments, was not addressed.

A large positive correlation was found between total scores of the MABC and the PDMS-2 ($r = 0.76$) (Van Waelvelde et al. 2007a). This study also found a high correlation between the gross motor sub-scores ($r = 0.71$) and a lower, medium correlation between fine motor skills ($r = 0.48$). Although these correlations imply that these instruments measure similar constructs, there was low agreement in identifying children with MI, thus tests are not interchangeable.

A study also investigated the convergent validity of the MABC against the KTK in a dichotomy of children referred with expected motor impairment and non-referred children (Smits-Engelsman et al. 1998). There was a higher correlation between assessments in the referred group than the non-referred group, $r = 0.65$ and $r = 0.62$, respectively. Although there was some concordance between the tests, once again there was variance in the agreement between assessments in detection of motor impairment. This finding may be indicative that the MABC has stronger diagnostic properties within a clinical population.

A further study investigated the relationship between the ball catching and two dynamic balance tasks of the second band of the MABC and a ball catching task, along with the beam and jump components of the KTK (Van Waelvelde et al. 2004). Correlations varied from non-significant to highly-significant. Correlations between the ball catching task of the MABC and the ball catching test were significant for each age group. The jump and balance in walking tasks of the MABC were significantly correlated to the jump and beam walking tasks of the KTK for 7-8 year old children, but not 9 year old children. Also, a ceiling effect with the jumping in squares and walking tip-toe on line tasks of the MABC were detected. These tasks are revised in the new version of the MABC.
These validation studies highlighted some important general findings:

- Adaptations that needed to be made to the original MABC i.e. dynamic balance tasks.

- Although large positive correlations are found between the MABC and many broad based tasks, a large amount of independence still occurs between assessments, particularly in agreement between tests in the identification of children with motor impairments.
4.1.2.3 Finding of validation studies of the MABC-2

Table 14: Validation studies of the MABC-2 Test

<table>
<thead>
<tr>
<th>Study</th>
<th>Assessment</th>
<th>Population/Sample</th>
<th>Testing Procedure</th>
<th>Validated Against</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Henderson et al. 2007)</td>
<td>MABC-2</td>
<td>Not Addressed</td>
<td>Not Addressed</td>
<td>Not Addressed</td>
<td>Determined by experts in this area, unanimous that the content of the revised test is representative of the motor domain as specified by test developers i.e. content validity of test appears reasonable.</td>
</tr>
<tr>
<td></td>
<td>Content</td>
<td>Validity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Face</td>
<td>Validity</td>
<td></td>
<td></td>
<td>Face validity in manual from various experts administering test, appears to be based on MABC. Limitation: similar to content validity, based on subjective opinion as opposed to inherent psychometric, objective or numeric data.</td>
</tr>
<tr>
<td></td>
<td>Total Test</td>
<td>Score</td>
<td></td>
<td></td>
<td>Section and total test standard score correlations are evidence that the three sections of the performance test measure related but distinct motor skills.</td>
</tr>
<tr>
<td></td>
<td>Construct</td>
<td>Validity</td>
<td></td>
<td></td>
<td>Manual Dexterity correlated against: Aiming and Catching ($r = 0.26$), Balance ($r = 0.36$), Total ($r = 0.76$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Aiming and Catching correlated against: Balance ($r = 0.25$), Total ($r = 0.65$)</td>
</tr>
</tbody>
</table>
Balance correlated against: Total ($r = 0.73$).

<table>
<thead>
<tr>
<th><strong>Criterion related validity</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(Kavazi 2006)</strong></td>
</tr>
<tr>
<td><strong>Barnett et al. 2007 cited in Henderson et al. 2007</strong></td>
</tr>
<tr>
<td><strong>Siaperas et al. 2007 cited in Henderson et al. 2007</strong></td>
</tr>
</tbody>
</table>
There is limited preliminary evidence surrounding the psychometric properties of the MABC-2 reported, with most of the validation findings stated within the MABC-2 manual and unpublished (Henderson et al. 2007). Authors of this revised version state that the contents of the MABC version are sufficiently similar the MABC-2, thus psychometric properties of the original version are applicable to the revised MABC-2. However, a review of the MABC-2 found that evidence of the validity of the MABC cannot be generalised to the MABC-2 as the two versions are quite different (Brown and Lalor 2009).

Aspects of validity that are said to be established according to the authors include content validity and face validity (Henderson et al. 2007). However, these are purely subjective findings as determined by experts in the area and there is no strong objective or numeric data to support these types of validity.

The relationship of the three subtests of the MABC-2 with each other and total test scores were also investigated according to the manual. Each of the three components had a large correlation with the total test score, indicating that each of the subtests contribute to the total motor competence aimed to be assessed by the MABC-2 test. There was only a small to medium correlation between the three components denoting independence between these components and that they each assess different areas of motor competence.

Three tests investigating criterion-related validity are also outlined in the manual (Henderson et al. 2007). Kavazi (2006) correlated the manual dexterity subtest of the first band of the MABC-2 to Draw-a-man test ($r = 0.66$). Meanwhile, Barnett et al. 2007 cited in Henderson et al. 2007 investigated the agreement between the classification of children as Motor Impaired with the MABC and the MABC-2. The 20 subjects achieved the same percentile score on both assessments, indicating good agreement. Finally, Siaperas et al. 2007 cited n Henderson et al. 2007 assessed 25 children previously diagnosed with Asperger Syndrome with the third age band of the MABC-2. Fourteen children were classified as having a definite motor impairment, while a further three displayed a borderline motor impairment.

The primary limitations of the above assessments include:

- Studies are unpublished; hence the methodology employed is questionable.
- Very small sample sizes were included in each of these studies, reducing the external validity of the findings.
The major limitation of MABC-2 as can be seen by table 14 is lack of evidence supporting its construct validity including divergent/convergent validity, factor analysis validity, diagnostic validity, and/or discriminative validity (Brown & Lalor, 2009). Hence, the primary aim of future research into the psychometric properties of the MABC-2 should incorporate construct validity and compare this revised edition of the MABC to established assessments of motor development such as the MAND, BOTMP or PDMS.
4.1.3 Gaps in the literature:

- Given the prevalence of Motor Impairments in the school environment it is necessary for assessments to incorporate ecological validity into the testing procedure. This can be achieved through:
  
  o Assessing in groups within the school environment.
  
  o Assessing the manual dexterity components with the children seated in the regular classroom seating simulating the normal classroom situation.
  
  o Assessing the gross motor skills of the child in their regular school gymnasium.

- Importance of establishing validity, particularly construct validity of the MAND and the MABC-2 assessments to ensure they are assessing the components of motor development that they aim to assess.

- Although there is much validity surrounding the original MABC, there are limited validation studies of the revised MABC-2, thus reducing its strength as an assessment tool.

- MABC-2 is designed to assess the motor competencies of children with varying motor proficiency; however this has not yet been investigated and can be evaluated through determining the convergent validity with a test of motor proficiency such as the MAND.

4.2 Aims and objectives of the current study:

4.2.1 Aims:

a) To investigate the convergent validity between the total scores along with factors and subtests of the MAND and the MABC-2 within an ecologically valid environment.

b) To evaluate the agreement between both tests in discriminating between motor impaired and typically developing children.

c) To evaluate which components of the MABC-2 and the MAND are good at distinguishing motor impaired children from typically developing children.
4.2.2 Objectives:

- To investigate the convergent validity of the total test scores obtained by children in a mainstream Primary School when assessed using the MAND and the MABC-2.
- To investigate the convergent validity of the factors of the MAND and the subtests of the MABC-2 in 7-9 year old children.
- To determine whether the MAND and the MABC-2 identify the same children as being motor impaired.
- To evaluate the components that comprise the MAND and the MABC-2, and determine which tasks within each assessment are strong at distinguishing between motor impaired and typically developing children.

4.2.3 Hypothesis

The study aims to address paucities of evidence highlighted by previous studies (Tan et al. 2001, Van Waelvelde et al. 2007a, Brantner et al. 2009). It would be hypothesised that:

- There will be a high correlation between both the total scores and the components scores of the MABC-2 and the MAND as they are supposed to measure similar aspects of motor ability.
- Both tests will identify similar children with and without a motor impairment.
- Some tasks of the MAND and the MABC-2 will be stronger in distinguishing motor impaired from typically developing children through the child’s performance within these individual tasks.

4.3 Methodology

4.3.1 Study Design

This study aimed to investigate the convergent validity of the MAND and the MABC-2 when administered within an ecologically valid school environment. The study is a cross-sectional study looking at a convenience sample of children drawn from six randomly selected schools who are representative of the general population of children in mainstream schools. A quantitative approach was implemented within this study with each assessment categorically rating the motor performance of the child. Within this research an outside observer, the
physiotherapist, observes the motor functioning of the child within their natural setting, thus increasing ecological validity (Polgar and Thomas 2008).

4.3.2 Ethical Approval

Ethical approval was granted by the University of Limerick Research Ethics Committee prior to recruitment. The University of Limerick Child Protection Guidelines were adhered to at all times while conducting this study.

4.3.3 Participants

4.3.3.1 Recruitment

Children enrolled in Second class of mainstream primary schools in County Limerick were invited to partake in this project. These participants represented a convenience sample and give a general representation of a normal rural primary school population.

A list of 32 primary schools in county limerick was retrieved from a government site as was done for the reliability study. Irish speaking schools were excluded due to the lack of facilities to translate the assessments to Irish without reducing the stability of the tests.

Each school principal was sent a letter inviting the second class pupils within their school to participate in the study. The same 11 schools who agreed schools to participate in the reliability study agreed to participate in this study. From those who agreed to participate 6 schools were randomly chosen by an impartial external to make up the study sample for this validation study.

Each pupil within second class in each school was given an information leaflet for parents (Appendix F), Information Leaflets for pupils (Appendix G) and consent forms for both parents and children (Appendix H) for both the parent/guardian and child. A total of 141 children were invited to participate in the study and 114 consented giving a response rate of 77 percent. Written consent was obtained from each parent and child who participated (Figure 15).
Each participant also met the necessary inclusion and exclusion criteria enabling them to participate safely and effectively in this study (Table 15).

Table 15: Inclusion and Exclusion Criteria for subjects wishing to participate in the study

<table>
<thead>
<tr>
<th>Inclusion Criteria</th>
<th>Exclusion Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Participants were at least 7 years at the time of assessment which ensured they could be accurately assessed using the second band of the MABC-2.</td>
<td>1. Participants with difficulty understanding the English language who were not able to follow instructions of the manual correctly were excluded.</td>
</tr>
<tr>
<td>2. Participants were enrolled in mainstream Primary Schools in County Limerick for the academic year 2009/2010.</td>
<td>2. Children excluded from physical education within the school were excluded from this study.</td>
</tr>
<tr>
<td>3. Informed written consent was obtained from Parent(s)/Guardian(s) and the child.</td>
<td></td>
</tr>
<tr>
<td>4. Children had to have a level of cognitive development that allowed them to follow test instructions appropriately.</td>
<td></td>
</tr>
</tbody>
</table>
4.3.4 Outcome Measures

4.3.4.1 MAND:

The MAND is a test designed as a screening, evaluation and research tool for clinicians, therapists, educators and researchers (McCarron 1982). The MAND assesses the fine and gross motor performance of 3.5-18 year-olds.

Figure 16: McCarron Assessment of Neuromuscular Assessment Tool

The test consists of 10 motor tasks; 5 gross motor tasks and 5 fine motor tasks. The 5 gross motor tasks include: (a) Placing beads in a box as quickly as possible with one hand, (b) Threading beads onto a rod as quickly as possible, (c) Tapping each index finger in a rhythmic manner, (d) Turning a nut onto a bolt as quickly as possible and (e) Sliding a bead along a rod as slowing and carefully as possible while keeping the rest of the body as static as possible. Meanwhile, the 5 gross motor tasks include: (a) Testing hand strength with a hand-held dynamometer (b) Touching index finger between nose and other index finger in a coordinated sequence (c) Jumping forwards off using both feet simultaneously, (d) Walking heel-to-toe along a narrow line while maintaining balance and (e) Standing on one foot maintaining balance with eyes open first and then with eyes closed. These tasks assess both one- and two-hand dexterity, grip strength, jumping and balance (Tan et al. 2001). Children obtain raw scores during the test depending on how they performed on conducting the various tasks. Appropriate age related table of norms are utilised to convert raw scores to scaled scores. These scores represent each child’s performance in comparison to their age-matched
peers at each 6 month interval. The NDI may be considered to be a general measure of motor skills and is determined by first summing the scaled scores for each of the 10 tasks and then converting this sum to the NDI score. There is a table for children under 11 and a separate table for adolescents over 11, this allows for the shape of the distributions of the summed scaled scores (Table 14). This test was standardised on 2,000 U.S. children (McCarron 1982).

**Table 16: Classification of children using the MAND**

<table>
<thead>
<tr>
<th>Neuromuscular Developmental Index (NDI) Score</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;55</td>
<td>Severe Motor Delay</td>
</tr>
<tr>
<td>55-69</td>
<td>Moderate Motor Delay</td>
</tr>
<tr>
<td>70-85</td>
<td>Mild Motor Delay</td>
</tr>
<tr>
<td>&gt; 85</td>
<td>Typically Developing Children</td>
</tr>
</tbody>
</table>

The test-retest reliabilities of the MAND after a one month interval range from 0.67 to 0.98 (McCarron 1982). In a recent study, both the inter- and intra-rater reliability were investigated in a population of children in mainstream schools (Connell 2010). Inter-rater reliability was good (0.761) while intra-rater reliability was moderate (0.680). The concurrent validity has been established (Brantner et al. 2009, Tan et al. 2001, McCarron 1982). The content, construct and predictive validity of the MAND has also been established (McCarron 1982).

**4.3.4.2 Movement Assessment Battery for Children-2**

The Movement Assessment Battery for Children-2 consists of two independent instruments: a test and a checklist (Henderson et al. 2007). For the purpose of this validation study, the test component of the assessment was investigated.
The test consists of 8 items that evaluate fundamental motor skills; three manual dexterity, two throwing & catching and three balance tests. The test is comprised of three age bands designed for use with children aged 3-16 years. The items are slightly different for each age band but cover the same type of skills. Within this study, the second age band was utilised which focuses on assessing children aged 7-10 years. This includes three manual dexterity items: (a) placing pegs on a pegboard, (b) threading lace through a lacing board, (c) drawing trail 2; two aiming and catching items: (d) catching with two hands, (e) throwing beanbag onto mat; and three balance items: (f) one-board balance, (g) walking heel-to-toe forwards and (h) hopping on mats. Test administration takes approximately 20 to 30 minutes and should be conducted using the protocol outlined in the manual (Henderson et al. 2007). For each of the three components of the test; manual dexterity, aiming and catching and balance- and for the total impairment scores, age adjusted standard scores and percentiles are provided (Henderson et al. 2007). A traffic light system is then employed to classify children into motor impaired, borderline motor impaired or typically developing group (Table 17).
Table 17: Traffic light system for classifying children using the MABC-2

<table>
<thead>
<tr>
<th>Child’s Score</th>
<th>Total Test Score</th>
<th>Percentile range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Zone</td>
<td>≤ 56</td>
<td>≤ 5&lt;sup&gt;th&lt;/sup&gt; percentile</td>
<td>Significant movement difficulty</td>
</tr>
<tr>
<td>Amber Zone</td>
<td>57-67</td>
<td>5&lt;sup&gt;th&lt;/sup&gt;-15&lt;sup&gt;th&lt;/sup&gt; percentile</td>
<td>Child is at risk of having a movement difficulty; monitoring required</td>
</tr>
<tr>
<td>Green</td>
<td>&gt; 67</td>
<td>&gt;15&lt;sup&gt;th&lt;/sup&gt; percentile</td>
<td>No movement difficulty detected</td>
</tr>
</tbody>
</table>

The total test scores within the MABC-2 are comparable to the NDI scores equated within the MAND. Developmental norms for the MABC were established on children from Canada, the United States, and the United Kingdom (Henderson and Sugden 1992). Updated normative data was gathered using 1172 children for Great Britain and Northern Ireland between 2006 and 2007. It involved children from all age bands from 3-16 years and the sample was stratified for geographic region, population density, social class and race or ethnicity (Henderson et al. 2007). The MABC has been translated into several European languages and is extensively utilised internationally with norms also evaluated in Sweden, Japan, Netherlands, Hong-Kong and Singapore (Brown and Lalor 2009) and Australia (Livesey et al. 2007). The test-retest reliability of the MABC-2 has also been investigated (Visser and Jongmans 2004, Chow et al. 2002, Faber and Nijhuis van der Sanden 2004). The inter- and intra-rater reliability was investigated in the previous chapter and was found to be excellent and moderate, respectively. There is limited preliminary evidence about the MABC-2, and in a review of the MABC-2 it was found that evidence of validity of the MABC cannot be generalised to the MABC-2, as the eight components of the two versions are quite different (Brown and Lalor 2009). Within the manual the authors describe how they subjectively established the content validity, face validity and subtest correlations of the revised version of the MABC (Henderson et al. 2007). Three studies investigating criterion related validity are also outlined within the manual, however their methodology is questionable (Henderson et al. 2007).
4.3.5 Procedure

The testing was conducted in the middle of the school year between the months of February and April to ensure the children were familiar with their classroom environment. Each child was assessed using the MAND and MABC-2 tests. The MAND and the MABC-2 evaluate both qualitative and quantitative aspects of a child’s motor performance which is then compared to standardised age related norms. Each of these tests task approximately 20 minutes to administer per child.

Children were randomly assigned to groups of three to minimise selection bias and assessments were administered with children in these groups. Testing was conducted in the school to simulate the normal classroom environment and increase the ecological validity of the assessment procedure. This is different to testing children individually in a quiet environment, as outlined in the testing manuals (McCarron 1982, Henderson et al. 2007). For the manual dexterity and fine motor assessments children were seated at the tables and chairs that they are positioned in throughout the school year. Meanwhile, gross motor skills were conducted in the gymnasium in which the child participates in physical activity and play on a regular basis. Children wore their regular school clothes throughout the assessments, again increasing the ecological validity of the assessment procedure.

The MABC-2 and the MAND are intended to be standardised and quantitative methods of assessing motor skills, therefore close adherence to the procedures of the test administration described within the manuals were followed with minimal prompting incorporated into the testing (McCarron 1982, Henderson et al. 2007). The scoring was conducted using the exact procedure outlined in the MAND and the MABC-2. Each child's performance was documented on coded standardised assessment sheets throughout the testing procedure to prevent a detection bias and maintain anonymity.

Children were assessed by two trained physiotherapists who are familiar with the administration of the MAND and the MABC-2. Both examiners were familiar with the test apparatus and methods of scoring prior to testing, ensuring the focus of attention was directed towards the child’s behaviour rather than on the equipment or test procedures (Balakrishnan and Rao 2007). It was previously reported that motivation, concentration and relationship with tester may influence assessment in paediatrics (Geldhof et al. 2006). Hence, the same examiner who introduced and familiarised themselves to the children beforehand assessed the child on both the MAND and the MABC-2.
Both assessments were administered on the same day with a break being incorporated between both tests, this captured the child’s motor performance on a particular day while maintaining concentration and motivation (Van Waelvelde et al. 2007a). The order of administration of the tests was counterbalanced, alternative groups started with each assessment. This involved half the children being assessed with the MAND first and half with the MABC-2 first to prevent order effects of testing (Van Waelvelde et al. 2007a, Croce et al. 2001, Smits-Engelsman et al. 1998).

4.3.6 Planned Data Analysis

4.3.6.1 Preliminary analysis

All data was analysed using the Statistical Package for Social Sciences (SPSS) version 16.0. Preliminary analysis was conducted on all data to investigate if there is a violation of the assumptions of normality, linearity and homoscedasticity (Pallant 2007). As the sample was greater then 50 the Kolmogorov-Smirnov statistic was used to determine if the data is normally distributed with a non-significant result (significance value of more then .05) indicating normality. If data was normally distributed parametric analysis was implemented, however, if the data was not normally distributed non-parametric analysis would be the most appropriate form of analysis.

Descriptive statistics of the data was obtained including means and standard deviations of NDI and TIS to compare the distribution of scores obtained in this study to normative data.

4.3.6.2 Relationship between assessments

Correlation analysis was used to provide a numerical summary of the direction (positive or negative) and strength of the linear relationship between two continuous variables (Thomas et al. 2005). This form of analysis was used for this validation study as although both assessments are continuous scales, these scales are slightly different, thus intra-class correlation coefficients could not be implemented.

Prior to conducting Pearson and Spearman correlations, scatterplots investigating the relationship between the two scales were created. These were useful when using correlation analysis as they illustrate the relationship between the two variables through a visual medium. These plots are also advantageous as they highlight any outliers that may have occurred.
between the two variables. If perfect agreement occurred a straight line would be created, meanwhile if no relationship occurred between the two variables a circle of points would evolve with no clear pattern being created.

Pearson correlation coefficient were utilised to determine the relationship between normally distributed data. Meanwhile, for non-normally distributed data Pearson’s correlation coefficients were complemented by the non-parametric equivalent, Spearman rank order correlation.

Pearson correlation coefficients (r) have values ranging from -1 to +1. The sign in front of the coefficient indicates the direction of the relationship i.e. positive or negative correlation. A positive correlation indicates that as one variable increases, so does the other, whereas a negative correlation indicates that as one variable increases, the other decreases. Pearson product moment coefficient is designed for continuous variables. The size of the absolute value signifies the strength of the relationship. A perfect correlation i.e. 1 or -1 indicates that value of one variable can be found directly by determining the value of the other variable. Meanwhile, a value of zero indicates no correlation or relationship between the two variables. Although Pearson correlation coefficients give an indication of a relationship between two assessments, unlike ICC’s, they do not show the absolute values that the subject is achieving in each of the scales.

Table 18: Strength of Correlation (Cohen 1988, pp. 79-81 cited in Pallant 2007)

<table>
<thead>
<tr>
<th>Degree of Correlation</th>
<th>Numerical Value of Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>0.1-0.29</td>
</tr>
<tr>
<td>Medium</td>
<td>0.3-0.49</td>
</tr>
<tr>
<td>Large</td>
<td>0.5-1.0</td>
</tr>
</tbody>
</table>

Spearman rank order correlation is designed for use with ordinal level or ranked data and should be employed when data is not normally distributed and does not meet the criteria for Pearson’s correlation (Pallant 2007).
When looking at a correlation it is of utmost importance that the amount of variance between the two variables is also calculated i.e. coefficient of determination. This can be calculated using the following formula:

$$R^2 \times 100 = \text{Coefficient of Determination}$$

This coefficient is also important as it can be used to determine the amount of independence between both assessments through finding the amount of unexplained variance.

4.3.6.3 Agreement between assessments

The agreement between assessments in their classification of children was conducted using a similar method to that used in a recent study that investigated the agreement between the MAND and the original MABC (Brantner et al. 2009). The agreement between the MAND and the MABC-2 in their identification of children as having motor impairment as defined by the test criteria was also investigated. Children were separated into a dichotomy of motor impaired versus non motor impaired for both assessments. According to these dichotomies the children were placed into one of four categories within a table (See Table 19).

<table>
<thead>
<tr>
<th>MABC</th>
<th>Motor Impairment</th>
<th>No Motor Impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAND</td>
<td>(a)</td>
<td>(b)</td>
</tr>
<tr>
<td>Motor Impairment</td>
<td>(c)</td>
<td>(d)</td>
</tr>
</tbody>
</table>

The following calculations were conducted to determine:

- Overall decision agreement between the two tests
  - \( \{(a + d)/ \text{total sample} \} \times 100 \}

- Agreement in classification of children as motor impaired between the two tests
  - \( \{a/(a + b + c) \} \times 100 \}
4.3.6.4 Performance of Typically Developing Children versus Motor Impaired Children

The ultimate aim of assessments of motor competence is their ability to distinguish typically developing children from children experiencing motor difficulty. This quality of an assessment should be evident at both an overall level i.e. total performance and at a more in-depth subtest level. Within the final part of analysis the ability of each task within the MAND and the MABC-2 to differentiate typically developing from motor impaired children will be determined.

This calculation will be conducted by:

- Creating a dichotomy of typically developing and motor impaired children as classified by the MABC-2 and the MAND.
- Subsequent to this, calculating the mean scores of both groups of children on all variables of the MAND and the MABC-2.
- The final step will be the calculation of the percentage differences between mean performances of the typically developing and motor impaired groups in each of the components within the MAND and the MABC-2.

4.4 Results

4.4.1 Demographics of Participants

The participating children ranged from 7 to 9 years (Mean = 99.87 months; SD = 5.24 months). Within this sample there were 43 boys and 71 girls (Table 20).
Table 20: Gender and ages of children of the 6 schools who participated in the study

<table>
<thead>
<tr>
<th>School</th>
<th>Participants in each school</th>
<th>Boys</th>
<th></th>
<th></th>
<th>Girls</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>n</td>
<td>Age Range (months)</td>
<td>Mean age ± SD</td>
<td>n</td>
<td>Age Range (months)</td>
</tr>
<tr>
<td>A</td>
<td>13</td>
<td>5</td>
<td>92-95</td>
<td>93.60± 1.14</td>
<td>8</td>
<td>90-102</td>
</tr>
<tr>
<td>B</td>
<td>12</td>
<td>6</td>
<td>98-104</td>
<td>102.00± 2.28</td>
<td>6</td>
<td>94-106</td>
</tr>
<tr>
<td>C</td>
<td>20</td>
<td>7</td>
<td>92-106</td>
<td>99.28± 5.34</td>
<td>13</td>
<td>92-119</td>
</tr>
<tr>
<td>D</td>
<td>13</td>
<td>4</td>
<td>99-107</td>
<td>102.75± 3.50</td>
<td>9</td>
<td>92-103</td>
</tr>
<tr>
<td>E</td>
<td>23</td>
<td>0</td>
<td>* Girls only School</td>
<td></td>
<td>23</td>
<td>90-110</td>
</tr>
<tr>
<td>F</td>
<td>33</td>
<td>21</td>
<td>94-107</td>
<td>101.52± 4.58</td>
<td>12</td>
<td>94-107</td>
</tr>
</tbody>
</table>

4.4.2 Descriptive Statistics

Table 21: Descriptive Statistics (range, mean and standard deviations) for the dependent variables of boys and girls

<table>
<thead>
<tr>
<th>Variables</th>
<th>Boys</th>
<th></th>
<th></th>
<th></th>
<th>Girls</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Range</td>
<td>Mean</td>
<td>SD</td>
<td>n</td>
<td>Range</td>
</tr>
<tr>
<td>MAND</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDI</td>
<td>43</td>
<td>53-140</td>
<td>104.86</td>
<td>19.99</td>
<td>71</td>
<td>48-131</td>
</tr>
<tr>
<td>Bimanual Dexterity</td>
<td>43</td>
<td>35-120</td>
<td>88.60</td>
<td>24.26</td>
<td>71</td>
<td>30-120</td>
</tr>
<tr>
<td>Persistent Control</td>
<td>43</td>
<td>55-130</td>
<td>99.53</td>
<td>20.49</td>
<td>71</td>
<td>40-130</td>
</tr>
<tr>
<td>Kinaesthetic Integration</td>
<td>43</td>
<td>50-125</td>
<td>90</td>
<td>23.95</td>
<td>71</td>
<td>45-135</td>
</tr>
<tr>
<td>MABC-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIS</td>
<td>43</td>
<td>60-134</td>
<td>103.95</td>
<td>17.78</td>
<td>71</td>
<td>58-134</td>
</tr>
<tr>
<td>Manual Dexterity</td>
<td>43</td>
<td>6-19</td>
<td>12.77</td>
<td>4.20</td>
<td>71</td>
<td>5-19</td>
</tr>
<tr>
<td>Aiming and Catching</td>
<td>43</td>
<td>5-18</td>
<td>11.70</td>
<td>3.31</td>
<td>71</td>
<td>4-18</td>
</tr>
<tr>
<td>Balance</td>
<td>43</td>
<td>7-19</td>
<td>17.49</td>
<td>3.15</td>
<td>71</td>
<td>4-19</td>
</tr>
</tbody>
</table>
4.4.2.1 Descriptive Statistics

The Kolmogorov-Smirnov statistic indicated that data for TIS and NDI scores were normally distributed $p > 0.05$, hence parametric analysis were utilised with this data.

Subsequent to this, upon investigating the mean and the standard deviation it appeared that both data sets were very similar with the NDI scores having a mean of 104 and a standard deviation of 17.5 while the TIS has a mean of 103 and a standard deviation of 17. These results are very similar to the standardised expected scores according to normative data of the MAND with a mean of 100 and standard deviation of 15 being the normal range (McCarron 1982).

4.4.3 Relationship between tests

4.4.3.1 Correlations between overall performance in the MAND (NDI) and the MABC-2 (TIS)

As the data was normally distributed; parametric analysis was employed. To investigate the relationship between the two assessments Pearson product-moment coefficient was the statistical analysis utilised. Prior to conducting the Pearson’s Correlation a scatter plot was created of the NDI and TIS of the tests. This plot indicated a positive relationship between the TIS of the MABC-2 and the NDI of the MAND as the plot forms a line in an upward direction to the right of the graph. Much of the points are gathered around the line indicating a strong relationship between the results.
Figure 18: Scatterplot of relationship between total scores of the MAND (NDI) versus total scores of the MABC-2 (TIS)

The Pearson’s Correlation between the NDI and TIS was 0.673 indicating a large positive relationship between the results (Cohen 1988, pp. 79-81 cited in Pallant 2007). This had a significance of 0.000, indicating that there is confidence in these results obtained. Upon further investigation the co-efficient of determination indicated that the variance shared between the MAND and the MABC-2 was 45.3%, i.e. 45.3% explained variance. However, it must be noted that this indicates that although there is a strong relationship between both tests there is still a large degree of independence between both assessments with 54.7% unexplained variance.
4.4.3.2 Cross Correlations between Factors of the MAND and Subtests of MABC-2

When the cross correlations between each of the 8 subsections of the MABC-2 and the 10 subsections of the MAND were investigated the results were not reliable enough, hence they were not explored further. Consequently the cross correlations between the four factors of the MAND and the 3 subtests of the MABC-2 were conducted for this study.

The Kolmogorov-Smirnov statistic indicated that data for the four factors of the MAND and the 3 subtests of the MABC-2 were not normally distributed $p < 0.05$, hence non-parametric analysis along with parametric analysis were used to examine the data. To investigate the correlations between subtests of both tests Spearman rank order correlations were conducted. This statistic was supported through the calculation of the statistically stronger Pearson product-moment correlations.

The results of these cross-correlations are outlined in Table 22. Within the table the Spearman rho correlation coefficient is the top figure and the Pearson product moment correlation coefficient is below this.
Table 22: Spearman’s rho (top) and Pearson (bottom) Cross-Correlation Coefficients (r) between the McCarron Assessment of Neuromuscular Development Factors and the Movement Assessment Battery for Children 2 Subtests (n=114)

<table>
<thead>
<tr>
<th>Neuromuscular Developmental Index</th>
<th>Bimanual Dexterity</th>
<th>Persistent Control</th>
<th>Muscle Power</th>
<th>Kinaesthetic Integration</th>
<th>Total Impairment Score</th>
<th>Manual Dexterity</th>
<th>Aiming and Catching</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Impairment Score</td>
<td>.658** .673**</td>
<td>.436** .435**</td>
<td>.357** .395**</td>
<td>.261** .381**</td>
<td>.526** .563**</td>
<td>1.000</td>
<td>.790** .772**</td>
<td>.481** .655** .687**</td>
</tr>
<tr>
<td>Manual Dexterity</td>
<td>.497** .515**</td>
<td>.435** .452**</td>
<td>.234* .270*</td>
<td>.234* .277**</td>
<td>.264** .285**</td>
<td>.790**</td>
<td>.772**</td>
<td>1.000</td>
</tr>
<tr>
<td>Aiming and Catching</td>
<td>.348** .339**</td>
<td>.205* .166</td>
<td>.213* .207*</td>
<td>.208* .232*</td>
<td>.328** .314**</td>
<td>.481**</td>
<td>.466**</td>
<td>.226* .338** .328**</td>
</tr>
<tr>
<td>Balance</td>
<td>.486** .433**</td>
<td>.239* .208</td>
<td>.238* .205*</td>
<td>.147 .352**</td>
<td>.522** .474**</td>
<td>.655**</td>
<td>.687**</td>
<td>.338** .121 .118</td>
</tr>
<tr>
<td>Neuromuscular Developmental Index</td>
<td>1.000</td>
<td>.639** .669</td>
<td>.652** .731**</td>
<td>.466** .503**</td>
<td>.733** .734**</td>
<td>.658**</td>
<td>.673**</td>
<td>.497** .348** .486**</td>
</tr>
<tr>
<td>Bimanual Dexterity</td>
<td>.639** .669**</td>
<td>1.000</td>
<td>.226* .331**</td>
<td>.299** .317**</td>
<td>.275** .279**</td>
<td>.436**</td>
<td>.435**</td>
<td>.205* .239* .208*</td>
</tr>
<tr>
<td>Persistent Control</td>
<td>.652** .731**</td>
<td>.226* .331**</td>
<td>1.000</td>
<td>.126 .178</td>
<td>.421** .508**</td>
<td>.357**</td>
<td>.395**</td>
<td>.234* .230* .207*</td>
</tr>
<tr>
<td>Muscle Power</td>
<td>.466** .503**</td>
<td>.299** .317**</td>
<td>.126 .178</td>
<td>1.000</td>
<td>.134 .114</td>
<td>.261**</td>
<td>.234* .277**</td>
<td>.208* .147 .352**</td>
</tr>
<tr>
<td>Kinaesthetic Integration</td>
<td>.733** .734**</td>
<td>.275** .279**</td>
<td>.421** .508**</td>
<td>1.000</td>
<td>.526** .563**</td>
<td>.264**</td>
<td>.328**</td>
<td>.522** .474**</td>
</tr>
</tbody>
</table>
Upon analysing the cross correlations the important findings that emerged were divided into 2 groups.

4.4.3.2.1 Relationship between overall test performance and subtests/ factors of the assessments:

- Each of the factors of the MAND have a large correlation with the NDI scores ($r = 0.503 \rightarrow 0.734$).
- Each of the subtests of the MABC-2; manual dexterity, aiming and catching and balance have a medium to large correlation with the TIS; $r = 0.772$, $r = 0.466$ and $r = 0.687$ respectively.
- Each of the four factors of the MAND had a medium to large correlation with the TIS of the MABC-2 ($r = 0.381 \rightarrow 0.563$).
- Similar to the factors of the MAND the subtests of the MABC-2 each have a medium to large correlation with the NDI score of the MAND ($r = 0.339 \rightarrow 0.515$).

4.4.3.2.2 Relationship between subtests of the MABC-2 and factors of the MAND:

- There was a strong correlation between Kinaesthetic Integration and Persistent control factors of the MAND ($r = 0.508$).
- A medium correlation was also found between the bimanual dexterity factor of the MAND and the manual dexterity subtest of the MABC-2 ($r = 0.452$).
- A medium correlation was also discovered between balance within the MABC-2 and the muscle power factor of the MAND ($r = 0.352$). This is the highest correlation of the muscle power factor against all other subtests and factors.
- Kinaesthetic Integration of the MAND and the balance subtest of the MABC-2 have a large correlation ($r = 0.522$).
- The aiming and catching component of the MABC-2 had the lowest correlation with all subtests ($r = 0.118 \rightarrow 0.314$) and with the totals; NDI ($r = 0.339$) and TIS ($r = 0.466$).

4.4.4 Case Agreement between Tests

Of the 114 children in the sample, 15 were classified as having motor impairment on the MAND and 3 on the MABC-2, with only two cases being identified on both measures. 13 children were classified as having motor impairment by the MAND and not by the MABC-2,
1 child was identified as having a motor impairment by the MABC-2 and not the MAND (Table 23).

Parents and teachers of children identified as having a motor impairment were informed and a presentation for both parents and teachers about the importance of seeing a physician to follow up on the finding was conducted.

**Table 23: Case Agreement for Motor Impairment between the McCarron Assessment of Neuromuscular Development (MAND) and Movement Assessment Battery for Children-2 (MABC-2)**

<table>
<thead>
<tr>
<th>MABC</th>
<th>Motor Impairment</th>
<th>No Motor Impairment</th>
<th>Total (MAND)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAND</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor Impairment</td>
<td>2 (a)</td>
<td>13 (b)</td>
<td>15</td>
</tr>
<tr>
<td>No Motor Impairment</td>
<td>1 (c)</td>
<td>98 (d)</td>
<td>99</td>
</tr>
<tr>
<td>Total (MABC-2)</td>
<td>3</td>
<td>111</td>
<td>114</td>
</tr>
</tbody>
</table>

Using the above table the overall decision agreement and the decision agreement in classifying children with motor impairment between the MAND and the MABC-2 was calculated.

The overall decision agreement between both tests was 87.7% \{[(a + d)/total sample] \times 100\}. The consistency in classifying children with motor impairment between the MAND and the MABC-2 was found to be quite low at 12.5% \{[a/(a + b + c)] \times 100\}.  

108
4.4.5 Performance of Typically Developing Children versus Motor Impaired Children

The average performance of children was tabulated when the subjects were divided into motor impaired and non-motor impaired groups according to their classification on the MAND and the MABC-2 (Table 24 and Table 25). Children were classified as motor impaired if they received a NDI score of less than 85 in then MAND or scored ≤15th percentile on the MABC-2. Once this classification was made, a dichotomy between non-motor impaired and motor impaired children was created. The average performance of children in each of these groups was then calculated for total performance and individual task performance on the MAND and the MABC-2. Once these averages were calculated the magnitude of the differences between the performances of each group on the tasks were calculated. Upon analysing this difference, it is evident that motor impaired children performed lower, to varying degrees, in each of the individual tasks and components of the MAND and the MABC-2.
Table 24: Performance of Typically Developing versus Motor Impaired Children on all components of the MAND

<table>
<thead>
<tr>
<th>Task</th>
<th>Non Motor Impaired</th>
<th>Motor Impaired</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MAND</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beads in Box</td>
<td>9.3</td>
<td>4.7</td>
<td>49%</td>
</tr>
<tr>
<td>Beads on Rod</td>
<td>7.4</td>
<td>2.3</td>
<td>69%</td>
</tr>
<tr>
<td>Finger Tapping</td>
<td>11.6</td>
<td>9.9</td>
<td>15%</td>
</tr>
<tr>
<td>Nut and Bolt</td>
<td>10.3</td>
<td>5.4</td>
<td>48%</td>
</tr>
<tr>
<td>Rod Slide</td>
<td>10.3</td>
<td>6.6</td>
<td>36%</td>
</tr>
<tr>
<td>Hand Strength</td>
<td>19.0</td>
<td>17.5</td>
<td>8%</td>
</tr>
<tr>
<td>Finger-Nose-Finger</td>
<td>12.1</td>
<td>5.3</td>
<td>56%</td>
</tr>
<tr>
<td>Jumping</td>
<td>9.9</td>
<td>6.9</td>
<td>30%</td>
</tr>
<tr>
<td>Heel-Toe Walk</td>
<td>11.4</td>
<td>4.5</td>
<td>61%</td>
</tr>
<tr>
<td>Standing on 1 Foot</td>
<td>8.6</td>
<td>4.6</td>
<td>47%</td>
</tr>
<tr>
<td>NDI Score</td>
<td>109.1</td>
<td>75.3</td>
<td>31%</td>
</tr>
<tr>
<td>Bimanual Dexterity</td>
<td>91.0</td>
<td>54.1</td>
<td>41%</td>
</tr>
<tr>
<td>Persistent Control</td>
<td>106.1</td>
<td>75.3</td>
<td>29%</td>
</tr>
<tr>
<td>Muscle Power</td>
<td>120.9</td>
<td>110.3</td>
<td>9%</td>
</tr>
<tr>
<td>Kinaesthetic Integration</td>
<td>98.6</td>
<td>66.3</td>
<td>33%</td>
</tr>
</tbody>
</table>

*Figures in bold are those tasks in which children with motor impairments scored significantly lower than their typically developing peers*
Table 25: Performance of Typically Developing versus Motor Impaired Children on all components of the MABC-2

<table>
<thead>
<tr>
<th>Task</th>
<th>Non Motor Impaired</th>
<th>Motor Impaired</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MABC-2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placing Pegs</td>
<td>19.7</td>
<td>14.3</td>
<td>27%</td>
</tr>
<tr>
<td>Threading Lace</td>
<td>9.2</td>
<td>6.1</td>
<td>34%</td>
</tr>
<tr>
<td>Drawing Trail</td>
<td>6.6</td>
<td>5.8</td>
<td>12%</td>
</tr>
<tr>
<td>Catching with two hands</td>
<td>10.3</td>
<td>8.7</td>
<td>16%</td>
</tr>
<tr>
<td>Throwing Beanbag onto mat</td>
<td>10.4</td>
<td>9.1</td>
<td>13%</td>
</tr>
<tr>
<td>1 Board Balance</td>
<td>19.9</td>
<td>15.8</td>
<td>21%</td>
</tr>
<tr>
<td>Walking Heel-Toe Forwards</td>
<td>9.4</td>
<td>6.0</td>
<td>36%</td>
</tr>
<tr>
<td>Hopping on Mats</td>
<td>20.8</td>
<td>16.3</td>
<td>22%</td>
</tr>
<tr>
<td>Total Impairment Score</td>
<td>106.2</td>
<td>81.9</td>
<td>23%</td>
</tr>
<tr>
<td>Manual Dexterity</td>
<td>13.5</td>
<td>8.9</td>
<td>34%</td>
</tr>
<tr>
<td>Aiming and Catching</td>
<td>10.8</td>
<td>9.1</td>
<td>16%</td>
</tr>
<tr>
<td>Balance</td>
<td>18.0</td>
<td>14.1</td>
<td>22%</td>
</tr>
</tbody>
</table>

The following were some of the primary findings from this analysis outlined in Tables 24 and 25 above:

- Within the MAND both factor and individual tasks highlight that children with motor impairments scored significantly lower than their normal peers in tasks that require bimanual dexterity and persistent control. This is indicative that children with motor impairments have difficulty manipulating and co-ordinating the right and left side of their bodies.

- Typically developing children scored substantially higher than motor impaired children in manual dexterity tasks.
Within the MAND the bimanual dexterity factor had a large percentage difference between groups (41%), with the two tasks within this factor also having a large difference between typically developing and motor impaired children:

- Beads on Rod (69%)
- Nut and bolt (49%)

Also within the MAND another task requiring manual dexterity placing beads in a box demonstrated a large difference between both groups (49%).

- The MABC-2 also found that children with motor impairments scored substantially lower than normally developing children in the manual dexterity component (34%) which included:
  - Placing pegs (27%)
  - Threading lace (34%)

- Not a large difference between groups in the aiming and catching component of the MABC-2 with a low difference of 16%.

- Kinaesthetic integration factor of the MAND had very good discrimination power at distinguishing between typically developing and motor impaired children (33%);
  - Heel-toe-walk (61%)
  - Standing on one foot (47%)

These tasks are similar to two balance tasks of the MABC-2; however these had lower differences between the performance of both groups, heel-toe-walk forwards (36%) and one board balance (21%).

- Finger-nose task of the MAND demonstrated a large difference between both groups (56%).

- Muscle Power factor of the MAND (hand strength and jump) had a very small percentage difference between groups (9%).
4.5 Discussion

Establishing the validity of an assessment is crucial as validity is ‘the degree to which theory and evidence support the interpretation of a test’s scores in relation to the stated aims of the test’ (Henderson et al. 2007). Consequently, unless the validity of an assessment is established it is impossible to ascertain if the test is measuring correctly what it was designed to assess. A primary limitation of the MABC-2 and the MAND was the lack of studies investigating their construct validity, including divergent/convergent validity, factor analysis validity, diagnostic validity, and/or discriminative validity (Brown & Lalor, 2009). Hence, the primary aim of this study was to increase the body of evidence surrounding the construct validity of the MAND and the MABC-2 through determining the convergent validity of the assessments and their agreement in classification of children as motor impaired. Both of these assessments are comprised of subtests that examine similar areas of motor development, hence, the relationships between these components were also investigated.

4.5.1 Convergent Validity

The convergent validity between the MAND and the MABC-2 was found to be good upon initial analysis (r = 0.673) demonstrating a large positive relationship. However, upon further investigation there was a substantial amount of independence between these assessments highlighted with 54.7% unexplained variance. These findings are similar to a recent study investigating the concurrent validity between the MAND and the original MABC which found a large correlation between assessments (r = -.590) (Brantner et al. 2009). This study also highlighted the large amount of unexplained variance between these assessments and emphasised the amount of independence between both assessments. This weaker relationship between the revised version of the MABC and the MAND contradicts the hypothesis of Brantner et al. (2009) that there would be a larger relationship between the revised MABC and the MAND. This was anticipated as unlike the MABC, the MABC-2 is based on normative data and contains standard scores for the full range of motor abilities; hence similar to the MAND the MABC-2 is able to assess motor skills of various levels.

The correlation in the current study was also lower than the large correlation (r = .860) obtained in an earlier study that investigated the concurrent validity between the MAND and the MABC (Tan et al. 2001). However, the sample size in the current study (n = 114) is much larger than this previous study (n = 69) affording it greater external validity.
As both the MAND and the MABC contain subtests that would be anticipated to measure similar areas of motor proficiency such as manual dexterity, persistent control and balance (Table 24), a cross-correlation between these subtests was conducted. Through conducting these cross-correlations information was provided surrounding the nature and similarities/differences between the subtests of the MABC-2 and the factors of the MAND (Brantner et al. 2009). The primary finding of this analysis was that all factors of the MAND have a large correlation with the NDI scores indicating that each factor contributes to the overall performance of the child in the assessment i.e. good construct validity. This is similar for the MABC-2 with the manual dexterity and balance subtests having a large correlation with the TIS, while aiming and catching had a medium correlation denoting a poorer correlation with the overall motor performance. This indicates that the aiming and catching subtest of the MABC-2 does not reflect the overall performance of a child on the MABC-2. Consequently, this subtest should not be used independently to give a reflection of the child’s overall motor competence and clinicians should be aware that the individual item scores and the ball skills sub score needs to be treated with caution (Van Waelvelde et al. 2007b).

When the factors of the MAND were correlated against the TIS of the MABC-2 medium to large correlations were found, signifying that a relationship existed between the components tested in each assessment. This relationship was also detected between the sub-totals of the MABC-2 and the NDI scores of the MAND, suggesting that each factor of the MAND assesses motor abilities of children similar to the MABC-2. This indicates that although there is a large amount of independence between assessments, there are some similarities between the areas of motor competence being measured by the MAND and the MABC-2.

Upon investigating the tasks within the factors of the MAND and the subtests of the MABC-2 some similarities emerged and the following relationships between tests would be hypothesised (Table 26).
Table 26: Common factors hypothesised to emerge in tasks within the MAND and the MABC-2

<table>
<thead>
<tr>
<th>Factors of MAND</th>
<th>Tasks of MAND</th>
<th>Subtests of MABC-2</th>
<th>Tasks of MABC-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bimanual Dexterity</td>
<td>Nut and Bolt</td>
<td>Manual Dexterity</td>
<td>Threading lace</td>
</tr>
<tr>
<td></td>
<td>Beads on Rod</td>
<td>Aiming &amp; Catching</td>
<td>Catching with 2 hands</td>
</tr>
<tr>
<td>Persistent Control</td>
<td>Rod Slide</td>
<td>Manual Dexterity</td>
<td>Drawing Trail</td>
</tr>
<tr>
<td></td>
<td>Finger-Nose-Finger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscle Power</td>
<td>Grip strength</td>
<td>Balance</td>
<td>Hopping on mats*</td>
</tr>
<tr>
<td></td>
<td>Hopping*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kinaesthetic Integration</td>
<td>Heel-to-toe walking on line*</td>
<td>Balance</td>
<td>Walking heel-to-toe forwards*</td>
</tr>
<tr>
<td></td>
<td>Standing on one leg*</td>
<td></td>
<td>One-board Balance*</td>
</tr>
</tbody>
</table>

* These tasks are common to both assessments.

Other tasks that are common to both assessments are the use of one hand to place one item (beads/pegs) onto or into another (box/mat).

Upon examining the components within both assessments it would be anticipated that there would be a strong relationship between manual dexterity of the MABC-2 and bimanual dexterity of the MABC-2 as they both focus primarily on fine motor skills requiring manipulation of objects with the child’s hands. However, only a medium correlation was detected ($r = 0.452$), indicating that within both assessments slightly different areas of manual dexterity are assessed.

Similarly, a large correlation would be anticipated between the persistent control factor (rod-slide) of the MAND and the manual dexterity (drawing trail-2) subtest of the MABC-2 as slow, controlled movements are a requisite of both, however, only a small non-significant relationship emerged. This may have occurred as 7 and 8 year old children have been performing drawing tasks similar to that of the MABC-2 on a daily basis since they started school; however the rod-slide task of the MAND was a little more difficult as it was unfamiliar and required control of the whole body. Consequently, children had varying abilities when conducting this novel task and this fluctuating performance of individual children on the rod-slide task may have reduced the correlation between tasks.

A medium correlation was also revealed between the balance component of the MABC-2 and the muscle power factor of the MAND ($r = 0.352$). This is the highest correlation of the
muscle power factor against all other subtests and factors. This relationship may have occurred as the balance tasks of jumping and standing on one foot both required high lower limb strength to perform them effectively. This positive relationship between balance and dynamic strength was found within a previous study of 9 to 12 year old typically developing children (Wang and Chen 1999).

A large correlation was anticipated and occurred between the kinaesthetic integration factor of the MAND and the balance subtest of the MABC-2 \((r = .522)\). This can be attributed to the similar tasks of heel-toe walk and standing on one foot in both of these components.

Within the MAND a strong correlation was revealed between the kinaesthetic integration and persistent control factors \((r = 0.508)\). This can be explained as both tasks within each of these factors predominantly require concentration (Rod Slide and Standing on one foot) and coordination (Finger-nose and heel-toe walk) to enable the child to perform them effectively (McCarron 1982).

Also of note is the aiming and catching component of the MABC-2 which had the lowest correlation with all subtests \((r = 0.118 \rightarrow 0.314)\) and with the totals; NDI \((r = 0.339)\) and TIS \((r = 0.466)\). Similarly, poor correlations between the aiming and catching and other components of the MABC-2 were also found in a study investigating the construct validity of the MABC-2 (Henderson et al. 2007). This poor correlation could be due to the lack of consistency in the performance of children when performing these tasks and may be improved by increasing the number of trial attempts the child has before the formal trials are attempted (Van Waelvelde et al. 2003).

Although there is a large correlation between the total scores of the MAND and the MABC-2, it is evident that there is a large amount of independence between the assessments at a total and subtest level. This independence may be explained at an in-depth construct level as both assessments are based upon different theoretical foundations. The MAND is comprised of tasks included based on the neuropsychological theory and includes common tasks for all age groups (McCarron 1982). Contrary to this, tasks within the MABC-2 are based on functional skills and are specific to different age bands (Henderson et al. 2007).
4.5.2 Agreement between Assessments

The next aspect of validity that was investigated was the decision agreement between the MAND and the MABC-2. Upon initial examination through calculating overall decision agreement between assessments, there appeared to be good agreement (87.7%). However, the agreement between assessments in their classification of children as motor impaired was very poor (12.5%). Within this classification only two children were classified as motor impaired by both the MAND and the MABC-2. Meanwhile, thirteen children were classified as motor impaired by the MAND and non-motor impaired by the MABC-2. Similarly, one child was classified as motor impaired by the MABC-2 and non motor impaired by the MAND. This indicates that fourteen children were classified differently by either the MABC-2 or the MAND. Consequently, although these tests may measure similar constructs, they are not interchangeable and further assessment into the motor ability of the child is necessary.

This agreement was much lower than that between the original MABC and the MAND according to earlier studies (Brantner et al. 2009, Tan et al. 2001). The study by Tan et al. (2001) found the MAND to have good sensitivity and specificity when the MABC was the criterion measure, denoting good agreement between assessments. However, the more recent study by Brantner et al. (2009) found there was insufficient agreement between the MAND and the MABC in their classification of children as motor impaired. Although the authors of the MABC and the MAND indicate that the tests are designed for slightly different purposes, with the MABC primarily designed to identify children with motor impairment while the MAND aimed at measuring the motor competence of children with varying motor capacity, essentially both assessments should identify the same children with motor impairments.

Inconsistencies in the classification of children as experiencing motor difficulty may result in the misdiagnosis of children. This misdiagnosis, if a false positive, may put unnecessary pressure on the child and their parents to seek necessary treatment to overcome this “motor impairment”. However, more worryingly many children with motor impairments may go undiagnosed which can lead to the sequential development of numerous physical, psychological and social co-morbidities (Missiuna et al. 2004, Missiuna et al. 2007, Chen et al. 2009, Skinner and Piek 2001, Faught et al. 2005).
4.5.3 Performance of Typically Developing Children versus Motor Impaired Children on various component of the MAND and the MABC-2

The final aspect of the tests that was investigated was the ability of various tasks within the tests to distinguish between motor impaired and typically developing children. This analysis is important as it identifies the important components of the MAND and the MABC-2 that contributes to differentiation between typically developing and motor impaired children.

The manual dexterity components of the MAND and the MABC-2 were excellent at distinguishing between typically developing and motor impaired children as they had two of the highest percentage differences between groups, 41% and 34% respectively. These tasks included the bimanual dexterity factor (beads on a rod and nut and bolt) and the beads in a box task of the MAND. The manual dexterity components of the MABC-2 included placing pegs and threading lace. This large percentage difference between groups may be explained as children with motor difficulties, such as DCD, experience enormous difficulty with fine motor skills (Smits-Engelsman et al. 2001, Visser 2003, Missiuna et al. 2004). Subsequently, these manual dexterity tasks which are common to each of the assessments should be included in these assessments of motor development.

Within the MABC-2 test, the aiming and catching component did not highlight a large difference between both groups as children with motor impairments only scored 16% below that of their normally developing peers. This may be due to the large inconsistencies in the performance of various children in these tasks and indicates that these particular tasks should be modified to make them stronger in identifying children with motor impairments (Van Waelvelde et al. 2007b). This improved consistency with a higher number of repetitions of ball catching has been demonstrated in a study investigating ball skills of 7 to 9 year old children in mainstream schools (Van Waelvelde et al. 2003). The results of this study indicate that the rigorous standardised short ball catching test, consisting of 50 trials, is a reliable and valid instrument for measuring ball catching performance.

Another positive feature of the MAND is the kinaesthetic integration factor. This is comprised of the heel-toe walk and standing on the heel toe walk and stand on one foot tasks, both of which assess the proprioception of the child through elimination of visual input. This is accomplished though shutting eyes while standing on one foot and through walking backwards in the heel-toe walk. Contrary to this, elimination of visual input is not addressed
within the MABC-2 and it is interesting to note that there was a much smaller margin in the difference between children’s performance in the walking heel-toe forwards component of the MABC-2 (36%) versus the heel-toe walk of the MAND (61%). This difference between tasks may be related to the greater proprioceptive and sensory motor deficits that are experienced by children with motor impairments (Piek and Dyck 2004, Mon-Williams et al. 1999). The later study suggests that tasks requiring body-centred spatial judgements are more difficult for children with developmental motor delay than typically developing children.

This point is further highlighted through the poor performance of children with motor impairments in the finger-nose task of the MAND also 5.3 versus 12.1 for their normal counterparts, a 56% percentage difference between performances of both groups. A study investigating the perceptual control of manual pointing in children with motor impairment revealed that dependency on vision was much more pronounced in this group than their normal counterparts (Rösblad and von Hofsten 1992).

One factor of the MAND that was minimally affected by the presence of motor impairment was the muscle power factor (hand strength and jump) which revealed a minute 9% difference between groups. This is indicative that the performance of a child in the MAND is more reliant on various aspects of co-ordination and motor abilities than on the strength of the child. This contradicts the findings of an earlier study proposing that children with developmental coordination disorder produce significantly lower levels of maximum force when compared to their normally developing controls (Raynor 2001). A major limitation of this study was the limited sample size (n = 40), thus reducing the external validity and subsequent generalisation of the results.

4.5.1 Limitations
The results of the current finding must be interpreted with caution due to the following methodological limitations:

Although the sample size employed within this current sample was quite large (n = 114), a power calculation to determine the exact number of participants that should be included to achieve sufficient power to allow confident generalisation was not conducted. Hence, the external validity of the current study is questionable.
Another methodological factor that must be considered when interpreting the findings of this study is that this validation study was limited to the second band of the MABC-2, investigating children aged seven to ten years. Consequently, the findings may not be generalised to the first and third age bands and further validation studies replicating the current study are necessary to be conducted with these age bands.

A methodological limitation when considering the population of children who participated in this current study is that the children were recruited from mainstream primary schools. This population of children was investigated as it is within this environment that many children experience difficulties which often go unrecognised. A limitation of implementing the assessments with this population is that the tests are designed more specifically to look at children with motor difficulty; subsequently the results may be different within this population.

Children with attention deficits were included in the sample size. This was necessary as it has been proven that many children with attention deficits simultaneously experience motor difficulties (Piek and Dyck 2004). Studies have found that approximately half of children with ADHD experience motor difficulties (Piek et al. 1999, Pitcher et al. 2003). Although it is crucial to include these children as they are like to experience motor difficulty, a factor that must be considered is their inability to maintain concentration throughout the administration of both tests. This reduced concentration may result in inconsistencies in performance on both tests as the child may loose concentration in the test administered second. A counterbalanced approach to administering the test was incorporated to reduce a bias towards one test, however the discrepancies in the between test performances for each child could not be avoided if the child’s performance on each of these tests on the same occasion wanted to be captured.

A potential problem when investigating relationship between assessments may have been the difference in the scales of the MAND and the MABC-2 measuring the child’s motor performance. To ensure that this did not influence the relationship between the assessments, Z scores employed to standardise the two scales and appropriate correlations was conducted accordingly. The resulting correlations were identical to those obtained in previous correlation analysis; hence this was not a factor of concern.
4.6 Conclusion

This study aimed to implement motor assessments within an ecologically valid environment, encouraging and thus recognising the normal performance of children within their everyday school environment. It is important to conduct assessments within these environments as these are the environments in which children with motor difficulties experience these problems on a daily basis.

In a large sample of children aged 7 to 9 years attending mainstream primary schools, the convergent validity between the MAND and the second band of the MABC-2 demonstrated a large, positive correlation. However, upon further investigation it became apparent that a lot of unexplained variance exists between these assessments, hence although there are some similarities, there is too much independence to allow the assessments to be interchangeable. Cross-correlations between the subtests of the MAND and the MABC-2 also revealed a large amount of variance between the tests with correlations varying from small to large.

The overall agreement of the tests in their classification of children was quite good upon initial analysis, however when investigating their agreement in the classification of children as motor impaired the agreement was surprisingly low and unacceptable (12.5%). Although there are some differences in the assessments at a construct level with different theoretical foundations, this poor agreement is enormous and could result in detrimental effects if it leads to the misdiagnosis of a child.

Finally, individual factors and tasks within both the MAND and the MABC-2 which were strong at discriminating between typically developing and motor impaired children were identified. Items that excel in this area include; manual dexterity tasks and kinaesthetic integration tasks. Meanwhile, muscle power and aiming & catching did not demonstrate good discriminatory properties in separating these two groups.

Although this study adds to the paucity of evidence surrounding the construct validity including of the MAND and the revised MABC, further studies replicating the current study investigating the other two age bands are necessary to expand this current data to the overall validity between the MAND and the MABC-2. Recommendations for future research in this area are outlined in chapter 5.
Chapter 5: Discussion

5.1 Introduction

Motor development is described as the process through which a child acquires movement patterns and skills. This motor development is a continuous process that involves modification and maturation of several environmental and bodily structures (Malina 2004). This acquisition of motor competence is an important developmental task of the child as it provides a crucial medium through which the child can explore his/her environment and subsequently becomes an integral part of a child’s behavioural repertoire. However, not all children experience motor development at the same rate as their peers and do not achieve the necessary level of motor competence to participate in academic and social tasks that require a variety of fundamental movement patterns.

Children experiencing developmental delay and poor motor competence were previously described as being “clumsy”, however in recent years a more common terminology of Developmental Coordination Disorder (DCD) has been adopted (Sugden 2006, Polatajko et al. 1995). It has been found that children with DCD experience numerous co-morbidities, some are thought to occur simultaneously (Kaplan et al. 1998), however many occur sequentially due to the motor difficulties that the child is experiencing (Missiuna et al. 2004, Missiuna et al. 2007, Skinner and Piek 2001).

It has also been found that it is within the school environment when motor skills are a central part of the classroom and playground environment that children experience most of these difficulties (Missiuna et al. 2006a, Hamilton 2002, Miller et al. 2001). The importance of investigating the motor competence of children within their normal school environment is also recommended within the International Classification of Functioning, Disabilities and Handicaps (ICIDH). This emphasises that disability is not uni-dimensional but manifests at different levels of human functioning in the form of impairments, performance limitations and the experience of disadvantage (Simeonsson et al. 2003). Therefore by screening children for motor impairment within their natural school environment this child-environment interface causes a shift in the framework of child abilities from a medical to a broader biopsychosocial assessment of disability. However, in Ireland similar to numerous other countries screening for motor impairments in children is very limited and when it does occur it is normally conducted within a clinical environment which does not resemble the environment in which the child has to complete tasks on a daily basis.
Consequently, the purpose of the current research was to conduct an in-depth review of literatures surrounding DCD and difficulties the children experience within the classroom. This would inform which assessment tools currently used for clinical and research purposes as screening instruments would be most appropriate to be implemented within the school environment. Upon determining two appropriate motor assessments the psychometric properties of these assessments, reliability and validity, within the ecologically valid school environment were investigated. These psychometric properties are crucial to be confident in the results obtained when these assessments are administered within the classroom environment. The aspect of validity that was investigated was the convergent validity, in which a strong positive relationship was anticipated between both assessments. More importantly, the decision agreement between the assessments is crucial as it will determine if both assessments identified the same children with motor impairments and have strong screening properties.

5.2 Literature Review (Chapter 2)
Numerous studies surrounding DCD and motor difficulties experienced by children in schools were included in the literature review. Some of the primary findings were the use of DCD to describe these children with developmental motor delay, the numerous comorbidities associated with DCD, the difficulties experienced by children within the schools environment and the importance of early diagnosis facilitating subsequent intervention.

The later part of the review investigated common motor assessments used to identify children with motor impairments. Four motor assessments emerged, the BOTMP, PDMS, MABC and the MAND. A thorough review was conducted into various properties of each of these assessments and the following findings emerged. The BOTMP was found to be lengthy and not very sensitive in identifying children with motor impairments (Tan et al. 2001). The PDMS is designed to be administered with children aged 0-6, thus would not be suitable for most children within the school environment. Also, this assessment is time consuming to administer, taking up to an hour to administer on each child and was found to have poorer sensitivity than the MAND at identifying children with motor impairment (Van Waelvelde et al. 2007a). The MAND and the MABC were therefore chosen as the most appropriate assessments to be implemented within the school population. However, as the original
MABC was not available for the current study the revised version, the MABC-2, was included. Some of the positive aspects of each of these assessment tools include:

- They were both designed to identify children with motor impairments within clinical and research settings.
- The tasks included within each of the assessments involve motor skills required by the children to participate in classroom and playground activities on a regular basis.
- Both assessments are small and easily portable allowing them to be easily transported from school to school.
- Assessments are quick and easy to administer, approximately 20 minutes per child, facilitating large numbers of children to be screened over a small period of time.
- They are both norm referenced assessments allowing for a range of motor proficiency from poor to good to be evaluated.
- Both assessments were found to have high sensitivity in identifying children with motor impairments (Tan et al. 2001, Van Waelvelde et al. 2007a).

However, both assessments have a paucity of evidence surrounding validity, particularly within the school environment, warranting further investigation.

Although there are differences between both assessments, the tasks within each of the tests appear to measure similar areas of motor competence, therefore a high convergent validity and high case agreement between assessments would be anticipated.

5.3 Reliability Study (Chapter 3)

It is said that adequate reliability is a prerequisite to obtaining validity (Anastasi 1988). Given that the reliability of a scale can vary depending on the sample with which it is implemented it was of paramount importance that the reliability of both the MAND and the MABC-2 were investigated within the school population (Pallant 2007). More specifically, given that the larger validation study shall focus on children aged 7 and 8 attending mainstream rural schools in Ireland, this shall also be the population within which the reliability of the assessments will be investigated.
A very recent study investigated the inter- and intra-rater reliability of the MAND with 5-7 year old children in mainstream rural primary schools (Connell 2010). The study was conducted using a similar protocol to that recommended and employed in this particular study with children being assessed in groups of three within their normal school environment, maximising ecological validity. The inter-rater reliability was found to be good (ICC= 0.85) with the intra-rater reliability slightly weaker (ICC= 0.83). Both of these reliabilities were acceptable with ICC ≥.75 (Portney and Watkins 2007), subsequently no further investigation into the reliability of the MAND was necessary with the population included in the validation study.

Due to the popularity of the original MABC as an assessment of motor development in children there was much research investigating its psychometric properties, including reliability. Five studies that found the MABC to have good to excellent inter-rater and intra-rater reliability were outlined in Table 3. However, although the authors declare that psychometric properties of the original MABC are applicable to the revised MABC-2 as they assess the same motor skill constructs, revisions to the instrument effectively make MABC-2 a different instrument (Brown and Lalor 2009). This is especially pertinent for the second age band in which two age bands of the MABC were amalgamated to produce a single age band for children aged 7 though to 10 years old (Henderson et al. 2007).

Although there are some reliability studies investigating the reliability of the MABC-2, there are numerous methodological limitations reducing there applicability to the current study. These include, no study investigated the reliability of the second age band of the MABC-2, two of the studies are un-published, and Bland and Altman calculations were not used to analyse the data reducing the clinical significance of the results.

Subsequently, a study investigating the inter- and intra-rater reliability of the MABC-2 was conducted. 20 children aged 7-9 years were assessed on two occasions with a two week interval. On the first occasion a second rater observed and independently rated each child’s performance to determine inter-rater reliability. On the second occasion, exactly 2 weeks later at the same time and in the same location the assessment was re-administered to determine intra-rater reliability. ICCs and Bland and Altman calculations were conducted to determine relative and absolute reliability, respectively.

Inter-rater reliability was found to be excellent for Total Impairment Scores of the MABC-2 (ICC= 0.97) and varied from good to excellent for each of the three subtests. This good to
excellent reliability was also revealed with small means of differences in Bland and Altman calculations; however the 95% Limits of Agreement were quite broad which reduces the clinical significance of the reliability. Reasoning for this is likely to be the small sample size (Rankin and Stokes 1998).

Similarly to the results of the reliability study of the MAND, intra-rater reliability of the MABC-2 was found to be weaker than the inter-rater reliability. Moderate reliability was revealed for Total Impairment Scores obtained on the two occasions (ICC= .732). Similarly, moderate to good reliability was obtained for the three sub-tests of the MABC-2. The Bland and Altman calculations also supported the ICCs with moderate agreement between the two measurements identified through larger mean differences between measurements. However, similarly to the inter-rater reliability the 95% Limits of Agreement were quite broad reducing the clinical significance. Once again this could be attributed to the small sample size employed in the current study. The aiming and catching component was found to have the lowest reliability, which has been found in previous studies (Visser and Jongmans 2004) and it has been suggested that the reproducibility of the aiming and catching tasks may be increased by increasing the number of trial attempts that the child performs before the formal trial (Van Waelvelde et al. 2003).

Although the intra-rater reliability was not the ICC ≥ .75 value suggested for adequate reliability (Portney and Watkins 2007), the inter-rater reliability was excellent and this is the type of reliability that was important with reference to the validation study. Inter-rater reliability was more important than intra-rater reliability in the validation study as each assessment was only being administered once; therefore the reproducibility of results within each assessment was not investigated. However, two raters were administering both assessments to each child within the validation study. Although each child was being assessed with both the MAND and the MABC-2 by the same rater, it was important that the raters administered and scored the assessments correctly, identifying children with the same reduced level of motor competence as motor impaired. If the inter-rater reliability was poor and the raters were scoring the children differently it may have led to differences in their classification of the motor abilities of a child.
5.4 Validation Study (Chapter 4)

The primary objective of this thesis was to determine if assessments of motor development are strong enough to carry out their primary function correctly, i.e. identify children with motor impairments. Within this particular research, this function of these assessments was conducted within the school environment to increase the ecological validity of the findings. This objective was investigated through determining the convergent validity and case agreement between two popular assessments of motor development, the MAND and the MABC-2.

Previous studies have been conducted investigating the relationship between the MAND and the original MABC which had conflicting results (Tan et al. 2001, Brantner et al. 2009). These studies suggest that further investigation into the relationship between these two assessments was warranted. Furthermore, a novel version of the MABC, the MABC-2, was released which was based on normative data and similar to the MAND included standard scores for a full range of motor abilities (Brantner et al. 2009). In a review of this MABC-2 it had been highlighted that there was a lack of evidence supporting it’s construct validity, including convergent validity (Brown and Lalor 2009). Consequently, this study investigated the convergent validity and case agreement between the MAND and the MABC-2 within an ecologically valid environment.

114 children were included in this study, with each of them completing the assessment and being included for analysis. To optimise ecological validity, assessments were conducted with children in groups within their normal school environment, at their normal classroom desks or within the school gymnasium.

Correlation analysis was implemented to determine the convergent validity between total and individual scores of the two assessments. Case agreement between assessments was determined creating a dichotomy of motor impaired and non- motor impaired children. This was created by classifying children who were identified as having a mild motor impairment by the MAND or being borderline motor impaired by the MABC-2 as motor impaired and children scoring above 85 on then MAND and above the 15\textsuperscript{th} percentile of the MABC-2 as non-motor impaired. An additional analysis was conducted to identify which tasks within each of the two assessments are good at distinguishing between motor impaired and non-motor impaired children.
The primary findings of this validation study were:

- Initially there was a large, positive correlation between the total scores on both assessments (0.673), however upon closer examination a large degree of unexplained variance existed between assessments (54.7%). This indicates a high level of independence between the MAND and the MABC-2.

- At an in-dept factor and sub-test level, similar to total scores, there were medium to large correlations between both assessments (Table 20). However, a large degree of unexplained variance existed between assessments.

- The most pertinent finding was the poor case agreement between assessments in their classification of children as having a motor impairment, with only 12.5% agreement (Table 21). The MAND identified 15 children with motor impairments whilst the MABC-2 only identified 3 children with motor impairments. This finding would suggest that the MAND may be a more sensitive assessment within this general school population.

- Upon looking at individual tasks within assessments, the manual dexterity and kinaesthetic integration of the MABC-2 and the MAND are very good at differentiating motor impaired children from non-motor impaired children.

Overall, this study indicates that although a large positive relationship does exist between the MAND and the MABC-2, there is a large amount of independence between these assessments, particularly in their classification of children within a school environment, which suggests that these assessments are not interchangeable. The independence between the assessments in the areas of motor competence assessed, as demonstrated by the small to medium cross-correlations between subgroups and factors could cause the discrepancies in the classification of children as having a motor impairment on one test and not the other. Consequently, this poor case agreement between the assessments could be a reflection of the heterogeneity of the clinical population and the normal variance within a community sample.

With the MAND’s ability to identify more children with motor impairments within this study population and previous literature promoting the MAND as a popular instrument to be implemented in the general population, it may appear that this assessment could be more
versatile and suitable within this school environment. However, it is imperative that further research is conducted to determine a gold standard assessment tool to be used as a criterion to which other assessments can be compared.

5.5 Clinical Implications

The primary clinical implication of the current research which is clearly highlighted within the literature review is the importance of introducing screening of motor development of children. However, this screening must give an accurate description of the child’s motor ability. This can be achieved through:

- Screening children within their natural environment. The child’s school is an environment which challenges various motor capabilities of the child on a daily basis and is pertinent to the maturation of a child across many areas of development; intellectually, physically and socially. This screening is crucial from an early age to facilitate early intervention and prevent the development of co-morbidities.

- Using clinically robust and psychometrically sound assessments. It is crucial that the assessments that are implemented are clinically robust and have strong psychometric properties to accurately identify children who may be experiencing motor difficulties within this dynamic school environment.

- This thesis aimed to address this gap within the literature and revealed:
  
  - The MABC-2 has excellent inter-rater reliability and moderate intra-rater reliability when inaccurate 95% LoA are excluded due to the small sample size.
  
  - Although there is a high convergent validity between the MAND and the MABC-2, the decision agreement between the assessments in identifying children with motor impairment is quite low. Consequently the assessments can not be interchangeable and the MAND appears to be the more sensitive assessment for identifying children with motor difficulties within a school environment.
5.6 Recommendations

Recommendations for future research that emerged from the current thesis include:

- The poor case agreement between the MAND and the MABC-2 identified the need for further investigation into the validity of the popular assessments of motor development, such as those outlined in chapter two, to determine a gold standard motor assessment. This gold standard assessment can be used as a criterion measure against which other assessments can be validated and improved with the overall aim of improving the screening properties of these assessments at identifying children with delayed motor development.

- Further reliability studies should be conducted using the MABC-2 with the other two age bands to strengthen the findings of the current reliability study and increase the generalisation of the reliability of this assessment across all children aged 3 to 16 years.

- Further investigation into the convergent validity of the MAND and the MABC-2 should be conducted for different age bands to increase the generalisation of the current findings to children of all ages.

5.7 Conclusion

This thesis sought to address three gaps in the literature pertaining to motor development of children within a school environment.

- The extensive literature review indicated that it is crucial that children are assessed at an early age within their regular school environment to identify children with developmental motor delay. This review also analysed popular assessments that are currently used to assess the motor development of children and identified two robust assessments that could be utilised in the school environment; the MAND and the MABC-2. A limitation of these assessments was the paucity of evidenced surrounding some areas of their psychometric properties including reliability and validity; this directed the further two areas of this thesis. In anticipation that motor assessments may be introduced in schools it was important to establish the psychometric properties of these assessments within the school environment.

- As reliability is prerequisite to validity it was important to establish the reliability of the MAND and the MABC-2 within the school environment. The reliability of the MAND within this school environment was established in a recent study (Connell
2010). Subsequently, the second aspect of this thesis was a quantitative study into the reliability of the second age band of the novel MABC-2 within the school environment. This revealed excellent inter-rater and moderate intra-rater reliability.

- Once reliability was established, a large validation study was conducted to investigate the convergent validity and case agreement between the MAND and the MABC-2. This study revealed that although there was a large positive relationship between both assessments, a lot of independence and poor case agreement occurred between assessments. This indicates the difference in structure and classification of these assessments and highlights the importance for further investigation into the validity of these assessments. More importantly it demonstrates the importance of establishing a gold standard assessment of motor development for children which can be used as a criterion measure against which other assessments can be validated.
References:


Missiuna, C. and Ont, O. (2003) 'Children with developmental coordination disorder: At home and in the classroom'.


Appendix A: Ethical Permission

Dear Amanda, Laura

Many thanks for your revised Research Ethics application which has recently been reviewed by the EHSREC (Chair’s Action). The recommendation of the Committee is outlined below:

**Title of Research Project:** EHSREC09-54
To Investigate The Convergent Validity Between Two Tests Of Motor Proficiency For Children Within An Ecologically Valid Environment.

**Principal Investigator:** Amanda Connell
**Other Investigators:** Laura Cronin

**Recommendation:** Approved

Regards

Anne O’Brien
Administrator to EHS Research Ethics Committee
Appendix B: Request Letters and Information for Schools

Physiotherapy Department,
Health Sciences Building,
University of Limerick,
Limerick

3rd February 2010

Dear «Title» «Last_Name»,

My name is Laura Cronin and I am currently a research Chartered Physiotherapist within the Physiotherapy Department in the University of Limerick. I have research funding to investigate motor development of children in mainstream primary schools. Approximately 6% of children attending mainstream primary schools have motor difficulty. Motor skill development is considered a strong predictor of general health in children.

My research is investigating which motor development assessment might be most useful within a dynamic school environment. The study will involve an experienced Paediatric Chartered Physiotherapist and me visiting your school, along with other schools in County Limerick, and upon receiving parental and child consent, carrying out two short assessments on individual children in second class within the school. These visits would be during this spring term at dates that are convenient to you and the pupils. The assessments take approximately 30 minutes to administer per child and will cause minimal disruption to normal classroom activities. These assessments are safe and are similar to the classroom and playground activities the children do on a daily basis.

The benefits of your schools participation in this study is that these assessments can identify children that may present with these motor difficulties and identify if further intervention is necessary. I would be willing to give a talk to classroom teachers and/or parents surrounding motor problems that children may experience, associated social and attention problems and how simple strategies can be implemented both at home and in the school environment to enable the child’s full participation and prevent social isolation.
Thank you for taking the time to read this letter, I hope your school would be willing to participate in this study. If you have any enquiries regarding this study please do not hesitate to contact me at (087) 9042976 or laura.cronin@ul.ie.

Yours Sincerely,

________________________

Laura Cronin (MISCP)

Further Information Surrounding this Research

WHAT IS THE PROJECT ABOUT?

Recording children’s achievements on two widely used movement assessment tools; the McCarron Assessment of Neuromuscular Development and the Movement Assessment Battery for Children. This project also aims to seek information about the accuracy of these assessment tools when children are tested in their regular classroom environment as opposed to individually in a clinical situation.

WHY IS IT IMPORTANT?

The tool is used for screening children to see how well children can carry out movements and physical activities. It has been proven that children experience most movement difficulties within the classroom; therefore it is vital that these assessments should be able to identify children with problems in this environment.

WHAT DOES THE PROJECT INVOLVE?

The project will be carried out in the months between February and May. The researcher will assess the children using the McCarron Assessment of Neuromuscular Development and the Movement Assessment Battery for Children.

The MAND has 10 items; 5 looking at whole body movement and 5 looking at hand tasks. Meanwhile the Movement Assessment Battery for Children comprises of 8 tasks; 5 looking at whole body movements and 3 looking at hand tasks.

The testing will take place during school hours with as little as possible time taken from class. Testing should take approximately 30 minutes and both assessments will be conducted on the same day. As the testing will take place in the classroom, the classroom teacher will be present at all times. Testing will be conducted by a Chartered Physiotherapist familiar with the assessments in question.
WHAT ARE THE BENEFITS OF YOUR SCHOOL TAKING PART IN THE PROJECT?

Your school will be helping by providing important information about the accuracy of these assessments within the classroom. If there are any difficulties with physical activities these will be bought to your attention and can be dealt with.

WHAT ARE THE RISKS?

There are no extra risks compared to normal playtime activities in school. If any child is unhappy during the project activities they can stop without giving a reason.

WHAT HAPPENS TO THE INFORMATION?

This is a research project and there are strict rules about who sees the results; the results of the overall project will be used but information on individual children will remain private. The results of the project will add to our knowledge of the accuracy of these assessments at identifying movement problems. Parents may request information about their own child by contacting the researcher Laura Cronin (087-9042976).

WHO ELSE IS TAKING PART?

All Primary Schools in County Limerick are being invited to take part in this project.
WHAT TO DO?

If you are happy for your child to take part in the project, please complete and sign the "consent form" and return it to the school as soon as possible.

If you want further information before deciding, please contact me:
Laura Cronin.

If you do not want your child to be involved in this project you do not have to do anything further.

Thank you for taking the time to read this leaflet.

The Researcher: Laura Cronin is a Chartered Physiotherapist graduated from the University of Limerick in 2009. Upon completion of degree, she received funding to conduct postgraduate research into the area of movement abilities of children in mainstream primary schools to increase the evidence surrounding movement problems with children in mainstream schools.

Further information can be gained by contacting Laura on 087-9042376.

If you have concerns about this study please contact:
Chairman Education and Health Sciences Research Ethics Committee, University of Limerick, Limerick.
Tel: 061 234101

EVALUATING THE RELIABILITY OF
A MOTOR ASSESSMENT FOR
CHILDREN WITHIN SCHOOLS

A Masters project by a Chartered Physiotherapist, Laura Cronin, studying in the University of Limerick.

WHAT IS THE PROJECT ABOUT?

Recording children's achievements on a widely used assessment tool: the Movement Assessment Battery for Children-2.

Seeking information about the accuracy of this assessment tool when children are tested in their regular classroom environment as opposed to individually in a clinical situation.

WHY IS IT IMPORTANT?

The assessment is used for screening children to see how well children can carry out movements and physical activities. It has been proven that children experience most movement difficulties within the classroom, therefore it is vital that these assessments should be able to identify children with problems in this environment.
WHAT DOES THE PROJECT INVOLVE?
The project will be carried out in the months between April and May. The researcher will assess the children using the Movement Assessment Battery for Children -2.

The Movement Assessment Battery for Children comprises of 8 tasks: 5 looking at whole body movements and 3 looking at hand tasks.

The testing will take place during school hours with as little as possible time taken from class. Testing should take approximately 30 minutes and will be carried out over 2 days. Testing will take place within the school. Testing will be conducted by two Chartered Physiotherapists familiar with the assessment in question.

WHAT ARE THE BENEFITS OF YOUR CHILD TAKING PART IN THE PROJECT?

- Your child will be helping by providing important information about the accuracy of this popular assessment within the classroom.
- If there are any difficulties with physical activities these will be brought to your attention and can be dealt with.

WHAT ARE THE RISKS?

- There are no extra risks compared to normal playtime activities in school.
- If any child is unhappy during the project activities they can stop without giving a reason.

WHAT IF I DO NOT WANT MY CHILD TO TAKE PART?

- Your child can only take part in this project with your permission.
- Your child does not have to take part in this project if you or he/she does not want to.
- Children and their parents are free to withdraw from the project at any stage without giving any reason.

WHAT HAPPENS TO THE INFORMATION?

- This is a research project and there are strict rules about who sees the results; the results of the overall project will be used but information on individual children will remain private.
- The results of the project will add to our knowledge of the accuracy of these assessments at identifying movement problems.
- Parents may request information about their own child by contacting the researcher Laura Cronin (087-9042976).

WHO ELSE IS TAKING PART?

- All children in second class of your child’s school and other Primary Schools in Limerick are being invited to take part in this project.

ALL INFORMATION IS KEPT STRICTLY CONFIDENTIAL AND ONLY USED FOR THE PURPOSES OF THIS PROJECT

The project has full ethical approval from the University of Limerick Research Ethics Committee.
Would you like to take part in a project that will look at how you can do different tasks using your hands and legs?

What will you be asked to do?
In your classroom with your classmates, you will be tested twice using the set of games in the picture below.

**Movement Assessment Battery for Children-2**

**What is this test?**
This test is made up of games that include working with beads, tracing lines, walking on a line, hopping and standing on one foot.

**What will happen while you are doing these tasks?**
Your classroom teacher and I, Laura, will be present during the testing. I will show you how to do each test first and I will then mark how you do on the test.

**What if you do not want to do the tasks?**
If you do not want to do the tasks you do not have to take part and if you decide to drop out during the tasks you may do so without having to give any reason.

**Why should you take part in this study?**
By taking part you are helping us find out good these tests are at noticing if children have difficulties doing these games.  

**Because it will be fun!!**
Appendix E: Consent Form (Reliability Study)

Title: To investigate the reliability of the Movement Assessment Battery for Children-2 within an ecologically valid environment

Informed Consent Form

Please read the following questions and tick the boxes that you agree with:

<table>
<thead>
<tr>
<th>Statements</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have read and understood the subject information sheet.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I understand what the project is about, and what the results will be used for.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am fully aware of the assessment my child will carry out, and of the risks and benefits of the study.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I know that my child’s participation is voluntary and that I can withdraw from the project at any stage without giving any reason.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am aware that the results will be kept confidential.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The researcher conducting this study is Laura Cronin. If you have questions you wish to ask or issues you would like to clarify before you sign this form, or at a later stage, you may contact Laura Cronin (087) 9042976

SIGNATURE | BLOCK CAPITALS | DATE
--- | --- | ---
Child: | | |
Parent/Guardian: | | |
Tester: | | |
Appendix F: Information Leaflets for Parents - Validation Study

WHAT DOES THE PROJECT INVOLVE?

Recording children’s achievement on two widely used movement assessment tools: McGhie-Ronan’s Assessment of Neuromuscular Development and the Movement Assessment Battery for Children.

WHY IS IT IMPORTANT?

The tool is used for screening children to see how well children can carry out movements. It has been shown that children can carry out more movements in their regular classroom environment than outside of it. If you have concerns about this study and wish to contact someone independently, you may contact the Vice President of Research and Development’s Office. University of Limerick, Limerick, Tel 061 202022.

WHAT TO DO?

If you are happy for your child to take part in the project, please fill in and sign the consent form and return it to the school as soon as possible.

If you want further information before deciding please contact me, Laura Crean.

If you do not want your child to be involved in the project you do not have to do anything further.

Thank you for taking the time to read this leaflet.
WHAT DOES THE PROJECT INVOLVE?

The project will be carried out in the months between February and May.
The researcher will assess the children using the McCarron Assessment of Neuromuscular Development and the Movement Assessment Battery for Children.

The MAND has 10 items: 5 looking at whole body movement and 5 looking at hand tasks.

Meanwhile the Movement Assessment Battery for Children comprises of 8 tasks: 5 looking at whole body movements and 3 looking at hand tasks.

The testing will take place during school hours with as little as possible time taken from class. Testing should take approximately 30 minutes and both assessments will be conducted on the same day. As the testing will take place in the classroom, the classroom teacher will be present at all times. Testing will be conducted by a chartered physiotherapist familiar with the assessments in question.

Teachers will also be asked to complete a brief questionnaire about the everyday performance of the child on motor tasks. This questionnaire rates the child on a scale from 0 (very well) to 3 (not close).

WHAT ARE THE BENEFITS OF YOUR CHILD TAKING PART IN THE PROJECT?

• Your child will be helping by providing important information about the accuracy of these assessments.

• If there are any difficulties with physical activities these will be brought to your attention and can be dealt with.

WHAT ARE THE RISKS?

• There are no extra risks compared to normal playtime activities in school.

• If any child is unhappy during the project activities they can stop without giving a reason.

WHAT IF I DO NOT WANT MY CHILD TO TAKE PART?

• Your child can only take part in this project with your permission.

• Your child does not have to take part in this project if you or he/she does not want to.

• Children and their parents are free to withdraw from the project at any stage without giving any reason.

WHAT HAPPENS TO THE INFORMATION?

• This is a research project and there are strict rules about who sees the results: the results of the project will be used but information on individual children will be private.

• The results of the project will add to our knowledge of the accuracy of these assessments at identifying movement problems.

• Parents may request information about their own child by contacting the researcher Laura.

WHO ELSE IS TAKING PART?

• All children in second class of your child's school and other primary schools in Limerick are being invited to take part in this project.

ALL INFORMATION IS KEPT STRICTLY CONFIDENTIAL AND ONLY USED FOR THE PURPOSES OF THIS PROJECT
The project has full ethical approval from the University of Limerick Research Ethics Committee.
Would you like to take part in a project that will look at how you can do different tasks using your hands and legs?

What will you be asked to do?
In your classroom with your classmates, you will be tested using two sets of games in the pictures below.

What are these tests?
These tests are made up of games that include working with beads, tracing lines, touching your nose, tapping your finger, walking on a line, hopping and standing on one foot.

What will happen while you are doing these tasks?
Your classroom teacher and I, Laura, will be present during the testing. I will show you how to do each test first and I will then mark how you do on the test.

What if you do not want to do the tasks?
If you do not want to do the tasks you do not have to take part and if you decide to drop out during the tasks you may do so without having to give any reason.

Why should you take part in this study?
By taking part you are helping us find out good these tests are at noticing if children have difficulties doing these games.

Because it will be fun!!
Appendix H: Consent Form- Validation Study

**Title:** To investigate the validity between two motor tests: the McCarron Assessment of Neuromuscular Development and the Movement Assessment Battery for Children-2 within an ecologically valid environment

**Informed Consent Form**

Please read the following questions and tick the boxes that you agree with:

<table>
<thead>
<tr>
<th>Statements</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have read and understood the subject information sheet.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I understand what the project is about, and what the results will be used for.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am fully aware of the assessment my child will carry out, and of the risks and benefits of the study.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I know that my child’s participation is voluntary and that I can withdraw from the project at any stage without giving any reason.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am aware that the results will be kept confidential.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The researcher conducting this study is Laura Cronin. If you have questions you wish to ask or issues you would like to clarify before you sign this form, or at a later stage, you may contact Laura Cronin (087) 9042976.

<table>
<thead>
<tr>
<th>SIGNATURE</th>
<th>BLOCK CAPITALS</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parent/Guardian:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tester:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix I: Data Collection Forms

Second Age Band of the MABC-2

Manual Dexterity 1:

Placing Pegs:

Record preferred hand: R/L, Time taken (seconds), F for failure; R for refusal; I for inappropriate.

<table>
<thead>
<tr>
<th>Preferred Hand</th>
<th>Only 2\textsuperscript{nd} trial if first longer than time below</th>
<th>Non-preferred Hand</th>
<th>Only 2\textsuperscript{nd} trial if first longer than time below</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td>7:0-7:11</td>
<td>Trial 1</td>
<td>7:0-7:11</td>
</tr>
<tr>
<td></td>
<td>8:0-8:11</td>
<td></td>
<td>8:0-8:11</td>
</tr>
<tr>
<td></td>
<td>9:0-9:11</td>
<td></td>
<td>9:0-9:11</td>
</tr>
<tr>
<td></td>
<td>10:0-10:11</td>
<td></td>
<td>10:0-10:11</td>
</tr>
<tr>
<td>Trial 2</td>
<td>37 secs</td>
<td>Trial 2</td>
<td>47 secs</td>
</tr>
<tr>
<td></td>
<td>33 secs</td>
<td></td>
<td>41 secs</td>
</tr>
<tr>
<td></td>
<td>32 secs</td>
<td></td>
<td>36 secs</td>
</tr>
<tr>
<td></td>
<td>29 secs</td>
<td></td>
<td>34 secs</td>
</tr>
</tbody>
</table>

Manual Dexterity 2:

Threading Lace:

Record: Time taken (seconds), F for failure; R for refusal; I for inappropriate.

<table>
<thead>
<tr>
<th>No. of secs</th>
<th>Only 2\textsuperscript{nd} trial if first longer than time below</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td>7:0-7:11</td>
</tr>
<tr>
<td></td>
<td>8:0-8:11</td>
</tr>
<tr>
<td></td>
<td>9:0-9:11</td>
</tr>
<tr>
<td></td>
<td>10:0-10:11</td>
</tr>
<tr>
<td>Trial 2</td>
<td>37 secs</td>
</tr>
<tr>
<td></td>
<td>34 secs</td>
</tr>
<tr>
<td></td>
<td>29 secs</td>
</tr>
<tr>
<td></td>
<td>27 secs</td>
</tr>
</tbody>
</table>

Manual Dexterity 3:

Drawing Trail 2:

(Note: BIC Atlantis pen to be used)

Record preferred hand: R/L, Time taken (secs.), F for failure; R for refusal; I for inappropriate.

<table>
<thead>
<tr>
<th>No. Of errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
</tr>
<tr>
<td>Trial 2</td>
</tr>
</tbody>
</table>
Aiming & Catching 1:

Catching with two hands:

(Note: With a bounce at 7 and 8; without a bounce at 9 and 10)

Record: Number of correctly executed catches; R for refusal, I for inappropriate.

Practice: [Blank]

10 Trials: [Blank] [Blank]

Total: [Blank]

Aiming and Catching 2:

Throwing Beanbag onto Mat:

(Note: Target is the orange circle, not the whole mat)

Record: Number of successful hits; R for refusal, I for inappropriate.

Practice: [Blank]

10 Trials: [Blank] [Blank]

Total: [Blank]

Balance 1:

One-Board Balance:

Record: Time Balanced; R for refusal, I for inappropriate.

<table>
<thead>
<tr>
<th>No. of secs.</th>
<th>No. of secs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Leg</td>
<td></td>
</tr>
<tr>
<td>Trial 1</td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
</tr>
<tr>
<td>Left Leg</td>
<td></td>
</tr>
<tr>
<td>Trial 1</td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
</tr>
</tbody>
</table>
Balance 2:

Walking heel-to-toe forwards:

Record: Number of correct consecutive steps from the beginning of the line; whether entire line was walked successfully; R for refusal; I for inappropriate.

(Note: Do not administer a second trial if the child completes 15 steps OR completes the whole line in fewer than 15 correctly executed steps.)

<table>
<thead>
<tr>
<th>No. of steps</th>
<th>Entire Line?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td>YES/ NO</td>
</tr>
<tr>
<td>Trial 2</td>
<td>YES/ NO</td>
</tr>
</tbody>
</table>

Balance 3:

Hopping on Mats:

Record: Number of correct consecutive hops (maximum of 5); R for refusal; I for inappropriate.

(Note: do not administer a second trial if the child completes 5 perfect hops on the first trial.)

<table>
<thead>
<tr>
<th>Right Leg</th>
<th>No. of hops</th>
<th>Left Leg</th>
<th>No. of hops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td></td>
<td>Trial 1</td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
<td>Trial 2</td>
<td></td>
</tr>
</tbody>
</table>
# Data Collection Sheet for the MAND

## MAND SUMMARY SHEET

**Name:**

**Age:**

**Sex:**

**Hand Preference:**

1. **Beads in Box** (# placed in 30 seconds)
   - Right _____ + Left _____ = Score

2. **Beads on Rod** (# of cylinders placed in 30 seconds)
   - Eyes Open _____
   - Eyes Closed _____
   - Total =

3. **Finger Tapping** (use score sheet)
   - Right _____ + Left _____ = Score

4. **Nut and Bolt** (# of seconds to complete task)
   - (Large) 100 - _____ =
   - (Small) 100 - _____ =
   - Total =

5. **Rod Slide** (use score sheet)
   - Right _____ + Left _____ = Score

6. **Hand Strength** (best of two trials with each hand)
   - Right _____ + Left _____ = Score

7. **Finger-Nose-Finger** (use score sheet)
   - Eyes Open _____
   - Eyes Closed _____
   - Total =

8. **Jumping** (use score sheet)

9. **Heel-Toe-Walk** (use score sheet)

10. **Standing On One Foot** (# of seconds up to 30)
    - Eyes Open, Right _____
    - Eyes Open, Left _____
    - Eyes Closed, Right _____
    - Eyes Closed, Left _____
    - Total =

    **Score**

    **Gross Motor Total**

    **TOTAL**

## HAND PREFERENCE, LATERALITY AND FATIGUE INDICES

<table>
<thead>
<tr>
<th>RIGHT</th>
<th>LEFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>Scaled</td>
</tr>
<tr>
<td>RBB</td>
<td>LBB</td>
</tr>
<tr>
<td>RFT</td>
<td>LFT</td>
</tr>
<tr>
<td>RHS</td>
<td>LHS</td>
</tr>
<tr>
<td>(\Sigma) SCALED</td>
<td>(\Sigma) SCALED</td>
</tr>
<tr>
<td>(M) SCALED</td>
<td>(M) SCALED</td>
</tr>
</tbody>
</table>

**RIGHT HPI**

**LEFT HPI**

**HPI DIFF.**

**RFI**

**LFI**

*RIGHT PREFERRED: (R-L) / R

*LEFT PREFERRED: (L-R) / L

156