The progression over time of profiles of children with Developmental Coordination Disorder

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The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

Assertion of moral rights:

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Jonathan Richard McQuillan (15.2.1972 – 13.7.2017)

Gerald Spinks (Gerry) McQuillan (18.1.1932 – 8.1.2018)

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Abstract

Aim: To investigate the characteristics of children with DCD with different severity of motor ability and compare motor progression over time.

Introduction: Children with DCD have difficulty in the development of motor coordination and learning new motor skills. Empirical and professional evidence suggests that they differ from typically developing children, but also suggest that they are heterogeneous in nature. DCD commonly overlaps with other developmental disorders. Studies have used different cut-off points for motor impairment and yet little is known whether children's motor progression differs for these different cut-offs or the impact on participation in physical activity (PA).

Method: An ecological mixed methods study design was used. Children had detailed profiles compiled of their individual characteristics and context. DSM-5 criteria were applied to identify children with and without DCD. Repeated motor measurements over 2 years measured motor stability or change. A case study approach identified a subset of children to interview about their experiences of participation in PA. Data analysis considered group comparison and individual motor progression through a dynamical systems lens.

Results: Children were categorized according to motor ability: ≤5th percentile, 6-16th percentile and ≥25th percentile on MABC2. Children in the lowest motor ability group had distinct characteristics. They had significant differences between their motor performance and the other groups, both at baseline and over time. It was characterized by stable, persistent and poor motor performance, while the other two groups were more variable over time.

Conclusion: Children ≤5th percentile of MABC2 appeared to have special characteristics in motor and non-motor domains. These were less variable and different to both typically developing children and to children with milder motor impairment. The results point the way to differential intervention according to the nature and severity of the characteristics in DCD in both the motor and non-motor domains.

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Abbreviations

ADHD: Attention deficit and hyperactivity disorder

APA: American Psychiatric Association

ASD: Autistic spectrum disorder

BOTMP: Bruininks- Oseretski Test of Motor Proficiency

CCC2: Children's Communication Checklist 2

CP: Cerebral palsy

CNS: Central nervous system

CSAPPA: Children's self perception of adequacy in, and predilection for physical activity

DAMP: Disorders of attention, motor control and perception

DCD: Developmental coordination disorder

DCDQ: Developmental coordination disorder questionnaire

DSM: Diagnostic and statistical manual

EACD: European academy for childhood disability

GLM: General Linear model

ICD: International Classification of Diseases

ICF: International Classification of Function, Disability and Health

IQ: Intelligence Quotient

IT: Information Technology

KBIT2: Kaufman Brief Intelligence Test 2

LI: Language impairment

MABC2: Movement Assessment Battery for Children 2

MD: Muscular dystrophy

MID: Minimum important difference

MLD: Moderate learning difficulty

MLM: Multi level model

NTT Neuromotor task training

PA: Physical activity

PAC: Perceived athletic competence

PE: Physical education

PDD: Pervasive developmental disorder

RD: Reading disorder

SDC: Smallest detectable change

SDD: Smallest detectable difference

SDDMF: Specific developmental disorder of motor function

SES: Socio-economic status

SLI: Specific language impairment

SNAP: Swanson, Nolan & Pelham Questionnaire

SPSS: Statistical Package for Social Sciences

TDC: Typically developing children

WHO: World Health Organisation

CHAPTER 1 INTRODUCTION

1.1 Research context and my interest in DCD

My interest in Developmental coordination disorder (DCD) developed during my career in the National Health Service as an occupational therapist. My work in child development teams entailed a comprehensive follow up for all babies born prematurely. It was apparent that these children were at greater risk of all kinds of developmental problems and required access to a range of health and education professionals. I encountered children with cerebral palsy (CP) who were such a diverse group in terms of their array of perceptual and motor problems, type (spastic, dystonia, ataxia), level and distribution of disability (for example diplegic, hemiplegic or quadriplegic) and fluctuating and abnormal muscle tone, all of which had a huge impact on their functional abilities. In addition many of these children had associated difficulties in learning, vision and or hearing, but conversely many others had no sensory problems and normal intelligence.

I encountered another group of children, who despite average intelligence and no reported CNS damage, encountered many of the motor and perceptual problems that the children with cerebral palsy met but to a lesser degree, yet with functional impairment significant enough to impact on everyday life. These children were labelled ‘dyspraxic’ (later to be called developmental coordination disorder). They too appeared to be a diverse group. Some had poor balance and poor gross motor skills whilst others mainly had difficulty with fine motor skills. Some encountered great difficulty planning an action, whilst others could plan but had great difficulty executing the action or task sufficiently well. Handwriting emerged as a huge problem for a significant proportion of the children and was the most frequent reason for referral. Yet when the children were examined more closely many were found to have additional specific learning difficulties, particularly in reading and spelling which only compounded the writing difficulty. Many also had attention and social difficulties.

Further interest led me to undertake a school-based project investigating a group of primary school children with DCD and poor handwriting. The findings appeared to support the hypothesis that the children with DCD had a different profile of results compared to the control poor hand writers without DCD and that the nature and severity of their handwriting difficulties was much more severe. However, small sample size should lead to the results being interpreted with caution.

After changing jobs and establishing an independent practice, I discovered an even more diverse range of profiles, with many more of the children meeting the criteria for two or even three developmental conditions (including DCD). This presented more questions. Why was it so difficult for parents to get the full extent of their child's needs acknowledged by statutory services, particularly if their child met criteria for more than one condition? Why did some children improve and gain specific skills but were not able to generalize them? Why did some children make rapid gains in motor development and others small incremental gains? Some children appeared to have severe motor impairment scores yet succeed in certain sports, why? Could there be different subtypes of DCD? Would they be associated with the type and number of other developmental conditions? Would they change over time with maturity? How much did family or school influence participation outcomes for children with DCD? These questions are important when considering policy for intervention for children with DCD. Study for a PhD seemed to be the logical strategy to answer some of these questions.

1.2 Purpose aims and objectives

The aim of this thesis was to examine the characteristics of children as potential underlying reasons for heterogeneity and the varied motor course found in children with DCD.

The study adopted an ecological approach using Bronfenbrenner's bio ecological framework to guide data collection in a prospective longitudinal study

over two years. DSM5 criteria were used to identify 7-14 year old schoolchildren with and without DCD and they were categorized according to the severity of their motor impairment using the MABC2 at the start of the study.

Repeated measures of motor performance were collected alongside contextual data for each child. The results were analysed using both the conventional general linear methods for group comparison and non-linear case analysis.

A dynamical systems theoretical approach to motor development was used to interpret the findings, with particular note of the inter- and intra-individual variability in motor progression and proposed as a means to identify children at risk of a more persistent problems and worse prognosis. A differential approach to intervention may be appropriate for this group of children.

Key words:

DCD, longitudinal, motor variability, ecological

In order to address these objectives the follow research question was adopted

Question: How do the profiles of children with DCD change over time?

1 What are the characteristics of children with different severities of DCD compared to children without DCD?

These included their:

- Motor characteristics
- Associated characteristics
- IQ
- Ability to take part in everyday activities
- Socio-economic and family context
- Self-perception of their adequacy, enjoyment and predilection to participate in physical activity

2.1 How stable are the motor characteristics or do they change over time?

2.2 How consistent are their self-perceptions of their adequacy, enjoyment and predilection to participate in physical activity or do they change over time?

3. How do the characteristics and stability or change in motor ability and self-perceptions impact experiences of participation in physical activity from the child's perspective?

1.3 Structure of the thesis

Chapter 2 introduces current knowledge of the characteristics of DCD. This includes the complex nature of DCD, the myriad of motor and non-motor symptoms associated with it and the heterogeneity often encountered in clinical practice and research. There is a synopsis of the secondary consequences and some of the serious outcomes that children with DCD may encounter without appropriate intervention. The role of overlapping conditions as a possible cause for heterogeneity is also discussed. The difficulty of distinguishing between the impact of DCD, it's secondary consequences, or the presence of overlapping conditions in terms of motor and other outcomes is highlighted. The importance of consensus agreements of criteria for the identification and diagnosis of DCD is also discussed in relation to the past and current DSM diagnostic criteria. As DCD is primarily a disorder of the development and acquisition of skilled motor control, the next chapter explores some of the theory behind these concepts

Chapter 3 introduces a definition of motor development and motor learning. Reviews of some of the theories that have informed our understanding of motor control and motor skill acquisition are explored. There is a discussion of how some of these theories have influenced research in DCD. The case is made for

an ecological approach to help capture some of the constraints and affordances that may influence the development of motor skills in DCD. This enables analysis from a dynamical systems perspective. The importance of active participation in physical activity for motor learning is highlighted. The role of variability in motor development is also discussed and proffered as a potential diagnostic and prognostic tool in atypical development. Without understanding typical motor development and how it progresses, it is difficult to establish whether children with DCD follow typical or atypical patterns of motor development over time

Chapter 4 discusses the course and prognosis for DCD by exploring some of the longitudinal studies in DCD research that have informed current understanding about the nature and outcomes of DCD. Issues are explored involving potential confounding influences on the motor and other outcomes in DCD research. This is discussed along with current understanding of self-perception of motor ability and the role it may have in participation in physical activity (PA) for children with DCD. Study design, sample identification, measurement issues, choice of data analysis and theoretical interpretation are also discussed in relation to current understanding of DCD and any potential gaps in research are highlighted. As both the course and prognosis for DCD has been reported as varied, it is important to examine the progression over time to determine which variables are important. An ecological approach is suggested to investigate motor progression in DCD from a dynamical systems perspective to capture some of these important variables.

Chapter 5 outlines the methodology for the prospective longitudinal ecological study using mixed methods in three parts.

Part I describes the method of identification and classification, by severity of motor ability, of school children with and without DCD according to DSM5 criteria. A description follows of the battery of tests and questionnaires adopted to undertake fine-grained analysis of the characteristics of children with DCD.

Part II describes methods for measuring any stability and change in motor ability and self-perception over time for typically developing children and those with DCD. It also describes how the children from each classification from part I were tracked and compared.

Part III describes how data from parts I & II may impact the children's experiences of participation in extra curricular physical activity (PA). Detail follows of the case study method, using a Quant-Qual priority sequence approach to determine the cases for interview. This is followed by description of cross case analysis to augment the data and help establish possible influences on participation in PA for children with DCD.

Chapter 6 outlines the results in three parts.

Part I describes the fine-grained characteristics of the children, grouped by classification of motor ability on MABC2 ≤5th percentile, 6-16th percentile and ≥25th percentile. Group comparisons of the baseline characteristics are presented.

Part II describes the stability or change in the motor abilities and self-perception of the children over time and changes in classification are reported. Trajectories of motor ability of the different group classification are compared with respect to the variability in motor performance between them.

Part III describes comparison of the participation in PA between the different groups of children, classified by motor ability. Self–perception, family attitude and resources are also compared to help determine the ecological circumstances of the children. Selected cases representative of typical and atypical cases from each group are reported and themes from their interviews are discussed in relation to their experiences of participation in PA.

Chapter 7 summarizes the study findings and discusses the practical and theoretical implications in relation to the existing body of knowledge on the nature of DCD with possible areas for future research. There is a discussion of the ecological design. This permits analysis to facilitate comparison at both the

group and individual level, and enable the results of motor stability or change to be interpreted through the lens of a dynamical systems approach to motor development. As a result, the importance of the role of variability and active participation in motor learning, for different groups of children, is highlighted and discussed. Suggestions are given about the possible need for differential intervention resulting from the variability. Findings associated with facilitating participation in PA, despite low motor ability are explored within the theories used in current DCD research and clinical practice.

CHAPTER 2 DEVELOPMENTAL COORDINATION DISORDER

This chapter begins by explaining current understanding of the complex nature of developmental coordination disorder (DCD). This will include discussion of how children with DCD present to teachers and clinicians, their many and diverse symptoms and the consequences of the symptoms, and secondary problems associated with these, on the children's daily lives. There is also a discussion of the difficulties of the identification of DCD and the need for consensus for diagnosis for both clinical intervention and for research. Some of the key features of DCD are highlighted, followed by a discussion of how DCD is currently identified and diagnosed along with some associated ongoing issues.

2.1 Definition of Developmental Coordination Disorder (DCD)

Developmental coordination disorder is classified as a neurodevelopmental disorder and subcategorized as a motor disorder in the current (2013) iteration of the American Psychiatric Association's (APA) Diagnostic and Statistical Manual of Mental Disorders (DSM-5). To receive the diagnosis, a child with poor motor control has to fulfil four criteria of diagnostic features. The first criterion is that a child's acquisition and execution of motor skills is substantially below that expected, given both the chronological age and opportunity for skill learning of the child. The second concerns the significant and persistent interference these poor motor skills have on activities of daily living, productivity and leisure and play. The third requires the onset of the motor symptoms to manifest in the early developmental period and the fourth concerns the cause of the motor problems, which states that the motor skills deficits should not be better explained by intellectual disability, visual impairment or a neurological condition affecting movement (e.g. cerebral palsy, muscular dystrophy or a degenerative disorder) (DSM-5, APA, 2013).

However, DCD has not always been recognized as a neurodevelopmental disorder and historically the children with the condition were referred to as ‘clumsy’ or maladroit (Dare & Gordon, 1970; Hulme & Lord, 1986; Losse et al., 1991). This terminology was not particularly helpful for either the children’s self esteem or for correctly identifying children with specific motor learning difficulties, as ‘clumsy’ tended to be an umbrella term for any type of motor difficulty with potentially different underlying causes. This was problematic for research as it led to difficulty in comparing groups of children. It also caused problems in clinical settings, as different intervention is required for conditions with different underlying causes. For example, a degenerative neurological condition causing poor motor control requires a different approach to intervention than poor motor control due to a developmental condition.

Another term commonly used to label children with these motor difficulties is dyspraxia. However, this is terminology borrowed from adult neurology literature, which describes a loss of function for planning motor behaviour, usually associated with damage to the parietal–occipital areas of the brain (Goodgold–Edwards & Cermak, 1990) and does not accurately reflect the developmental nature of the condition.

However, more helpful terminology was introduced when the World Health Organization (WHO) in 1992 and the APA in 1994 formally recognized the condition with agreed specific criteria for diagnosis. These different diagnostic criteria will be examined in turn and discussed later in the chapter as they reflect a progression in the understanding of the nature of DCD through evolving research. The term developmental coordination disorder subsequently became the internationally adopted term by researchers and practitioners (Sugden & Wade, 2013), which has enabled clearer identification of study participants and study comparison.

2.2 The nature of Developmental Coordination Disorder (DCD)

Despite Developmental Coordination Disorder (DCD) having been formally recognized since 1992, it is not well understood or recognised by the general population and could be classified as a 'hidden' disability. A recent international online survey of 1297 parents, teachers and physicians revealed that it is also poorly recognized by professionals (Wilson et al., 2013), as only 41% of paediatricians and 23% of General practitioners had knowledge of the condition. Harris et al. (2015) also suggested that although DCD is reasonably prevalent in the population healthcare professionals under-recognize it.

It is a developmental disorder and presents in early childhood, and although the children appear 'normal', parents often notice subtle differences in their children. For example, they may sit, crawl or walk later than other children and may have great difficulty acquiring basic dressing skills. However, without proper recognition or diagnosis it is difficult for parents to get help for their children.

Nevertheless, DCD is relatively common and is seen in about 5-6% of all children (APA, 2013), although not all children present the same clinical picture, and this may add to the difficulties with recognition and diagnosis. DCD is identified as a specific developmental disorder of motor skills that cannot be explained by a known medical disorder or intellectual retardation, but can interfere with daily life and so merits remediation (Henderson & Barnett, 1998). It is a condition characterized by difficulty learning new motor skills and difficulty in the development of motor coordination (Blank et al., 2012), which are considered core features.

Importantly, it is now accepted as a chronic disability, which significantly impacts on a child's ability to perform everyday motor-based tasks (Missiuna & Campbell, 2014) and so is beginning to be acknowledged as a serious disorder. There is evidence too that the motor coordination problems significantly interfere with school and everyday function (Wang, Tseng, Wilson & Hu, 2009;

Summers, Larkin & Dewey, 2008; Missiuna et al., 2008) and mounting evidence that these difficulties and their social and emotional consequences appear to persist into adulthood (Rasmussen & Gillberg, 2000; Missiuna et al., 2008, Kirby et al., 2008; Kirby, Edwards & Sugden, 2011). Although DCD is a disorder involving coordinated movement, it is often associated with a range of psychological problems (Missiuna & Campbell, 2014) and other non-motor difficulties (Dewey et al., 2002; Leonard & Hill, 2015; Wilson et al., 2017) that can also have serious negative consequences. Every class is likely to have a child with DCD and so is a condition of great importance to therapists and teachers alike.

2.2.1 Symptoms

Children with DCD are slower, less accurate and more variable in their motor skills than their typically developing peers (Geuze & Kalverboer, 1994; Cantin et al. 2007) (see Zwicker et al., 2012) for a review. This can impact most aspects of daily life and draw unwelcome attention from peers. Strength, power, speed and endurance are also lower in DCD than typically developing children (Hands & Larkin, 2002), leading to lower health-related fitness, and can present problems with play, sports and keeping up with their peers. The cause of DCD is unknown, but difficulties with perceptual skills have been a popular line of inquiry for researchers, but not without contention. For example, a meta-analysis by Wilson and McKenzie (1998) found a clear association between visual–perceptual deficits and poor perceptual–motor skills in children with DCD, but Geuze (2005) suggested that it is unclear how these visual-perceptual deficits affect perceptual- motor skills.

Wilson et al. (2013) conducted a meta-analysis of research literature from 1997-2011 and concluded that children with DCD present with patterns of deficits in predictive control of movement (internal modelling), rhythmic coordination and timing, dynamic control of posture and gait, catching and manual interception (interceptive action) and deficits in executive function. Practical examples of these deficits in a school child would be difficulty positioning him or herself on a sports field to receive a ball, difficulty keeping time in music or dance, slumping

in a chair, walking into doorways or objects in a classroom and difficulty organizing self and belongings. The suggestion is that children with DCD have a reduced ability to form internal models for action, instead having to rely on feedback (Wilson et al., 2013). A further review by Wilson et al. (2017) of DCD research on cognitive and neuroimaging findings found a broad cluster of deficits in motor learning processes, anticipatory control of movement and cognitive control. However, they concluded that current data do not allow prediction of whether a child with mild, moderate or severe DCD will present with a particular cluster of motor or cognitive issues (Wilson et al., 2017). The condition is not widely understood or recognized by teachers or medics and many of the children remain undiagnosed, left with a 'hidden disability' to cope with quite significant impairments in everyday function (Blank et al, 2012) and lower quality of life (Zwicker, Harris & Klassen, 2013).

2.2.2 Heterogeneity of symptoms in DCD

However, not all children with DCD present with the same symptoms. They can present with differing characteristics, which can include deficits in timing of motor response, deficits in sensorimotor integration and visual perceptual difficulties (Visser, 2007). This is acknowledged by researchers and widely accepted that children with DCD form a heterogeneous group (Dewey & Wilson, 2001; Jongmans et al., 2003; Wilson & McKenzie, 1998; Martin, Piek et al., 2010) with varying profiles of difficulties in the motor domain (Wilson et al., 2003), for example, poor balance but relatively unaffected fine motor control or vice versa, or indeed poor performance across all domains. Moreover, it is not unusual to find children with DCD who perform either at the same level or above their peers on a specific sensorimotor skill, yet have severe problems in another sensorimotor area (Visser, 2007). This is often confusing for parents and teachers who are unaware of DCD. Clearly, descriptive analysis of the various characteristics lacks authority and the identification and diagnosis of DCD is complex.

2.2.3 Non-motor symptoms and overlapping conditions

The presence of non-motor problems has also been well documented in DCD in areas such as attention and specific learning difficulties, perceptual difficulties, problems with self esteem, making friends at school and under achievement (Losse et al., 1991; Cantell et al., 2003; Jongmans et al., 2003). Indeed, attention problems are so commonly found accompanying motor coordination difficulties this led to the term DAMP (disorders of attention, motor control and perception) being introduced by Swedish researchers (Gillberg, 2003). Attention problems are also strongly associated with ADHD and the comorbidity of ADHD and DCD is reported to be as high as 50% (Missiuna et al., 2011; Pearsall-Jones et al., 2010). Many studies have been undertaken to establish the affect of attention on motor performance (Piek et al., 2004; Piek et al., 2007; Castelnau et al., 2007). A population cohort study provided further evidence for non-motor problems co-occurring with DCD and reported findings that children with DCD were at increased risk of wide ranging difficulties outside the motor domain (Lingam et al., 2010). However, there is some debate whether they represent separate but overlapping conditions (see Cairney, 2015, p18 for an overview).

Another consideration is that motor clumsiness has also been identified in children with other developmental conditions, for example dyslexia, attention deficit hyperactivity disorder (ADHD), specific language impairment (SLI), autistic spectrum disorder (ASD) (Piek et al., 2004; Hill, 1998; Hill, 2010; Kaplan et al., 1998; Green & Baird, 2005; Martin, Piek et al., 2010) and children with low birth weight or born prematurely (Foulder-Huges & Cooke, 2003). However, these findings have important implications and raise both theoretical and practical considerations, such as aetiological origins of the overlapping behaviours and call into question the specific nature of DCD. There have been previous arguments for a diffuse brain dysfunction termed ‘atypical brain development’ or ‘minimal brain dysfunction’ to explain these overlaps, rather than view DCD as a specific disorder, but ‘pure’ DCD does occur (Peters & Henderson, 2008). The concept of co-occurrence, continuum and comorbidity

is not without controversy (see Kaplan et al., 1998; Kaplan et al., 2001; Kaplan et al., 2006 for a discussion). However, the potential impact that the presence or absence of co-occurring conditions can have on the assessment and prognosis for children DCD should be accounted for in research. This will be discussed further in chapter four.

2.2.4 Problems associated with DCD and secondary problems

The effect of poor coordination and other non-motor problems can lead to children with DCD encountering significant difficulties in everyday life with profound impact. For example, children and adolescents with DCD are thought to be at increased risk for mental health problems, poorer psychosocial functioning and lower educational attainment (Losse et al. 1991; Rasmussen & Gillberg, 2000). Children with DCD have been reported to experience greater levels of anxiety than their typically developing peers (Pratt & Hill, 2011), lower self worth (Skinner & Piek, 2001) and poorer psychosocial adjustment (Dewey, Kaplan, Crawford and Wilson, 2002). However, it is not clear whether the motor difficulties, the non-motor deficits or the secondary difficulties relating to the impaired function produced by these difficulties are the cause. Missiuna & Campell (2014) proposed that sufficient evidence exists in the literature supporting negative mental health outcomes for children with DCD. However, they suggested the role that comorbidity of other disorders might play as primary or secondary stressors is largely unexplored.

2.2.4.1 The Environmental Stress Hypothesis and DCD

Cairney et al. (2013) proposed an environmental stress hypothesis model with which to explore the relationship between some of the primary and secondary factors that may mediate and mitigate risk factors associated with psychological problems and DCD. The model proposes that the primary stressor of poor motor coordination leads to a series of secondary stressors over time, which in turn lead to poor mental health (Harrowell et al., 2017). The model has been tested with a number of different samples, age groups and research designs, some of which have been replicated and provide support for the framework as a

causal network for the association between motor skills and internalizing problems (see Mancini et al., 2016 for a review).

One such study used the prospective longitudinal data from the UK Avon longitudinal study (ALSPAC) to assess the relationship between DCD and mental health outcomes in adolescents aged 16-18 years (Harrowell et al., 2017). Advantages of this population based study, apart from the large sample size (n=6902), is that children identified with DCD were defined by DSM –IV-TR criteria, assessed with three sub-tests of the Movement Assessment Battery for Children (MABC) (Henderson & Sugden, 1992) and included if they had an IQ > 70 and motor score ≤15th percentile. Thus some confounding variables could be addressed within the study and furthermore, detailed socio-economic status (SES) information and family medical and employment history was also available for analysis. They found support for the Environmental Stress Hypothesis and demonstrated longitudinally in a population cohort that poor mental health was an important consequence of DCD. Additionally, Harrowell et al. (2017) found that there were sex differences, adolescent girls with DCD were more likely to report emotional difficulties and depressive symptoms, and boys more likely to report peer problems. Importantly, they also found a mediating effect of social communication skills and self-esteem and posited that clinical support targeted at these domains may improve mental health outcomes for children with DCD, although this is yet to be tested empirically. Clearly this could have important implications for future intervention design and requires further study. One issue not reported in the study was any differential effect of the severity of motor impairment on outcome as all children ≤15th percentile of motor ability were included in the analysis.

2.2.4.2 The potential role of co-occurrence in DCD secondary problems

A recent pilot study by Dewey & Volkovinskaia (2018) aimed to address the question of the potential role that co-occurrence played in quality of life outcomes. They compared a group of adolescents with co-occurring DCD plus ADHD with a group of DCD alone, and with a group of typically developing children (TDC) to investigate the impact of the disorders on health-related

quality of life. They found no significant difference between the groups in total quality of life scores, but the group with ADHD and co-occurring DCD had significantly lower subscale scores for mood, emotions, school environment and financial resources and reported higher victimization. Although this was only a small study (n=44), it appears to suggest that children with DCD plus ADHD have more negative mental health outcomes than with DCD alone. Missiuna, Cairney et al., (2014) also found that children with both DCD and ADHD had significantly more symptoms of depression and anxiety than TDC in their population-based sample. It therefore appears to support the hypothesis that children with co-occurring DCD and ADHD may be at greater risk of negative mental health outcomes. A finding also supported by Rasmussen & Gillberg (2000), who found higher rates of mental health problems, alcohol misuse and ADHD in adults at 22 years with DCD diagnosed at 7 years old. The identification of disorders co-occurring with DCD is therefore imperative for future research and should also be considered in intervention design as there is the potential they may require different forms and intensity of intervention.

2.3 Impact of DCD on function and participation in daily life

DCD can affect efficient function in many areas in the daily life of a child (APA, 2013), which can cause frustration and lead to under achievement. Cermak, Gubbay & Larkin (2002) suggested that when considering the functional difficulties of children with DCD, it is not just whether the child can perform the task, but how much effort and time it takes to complete should also be considerations as these are critical elements for school success.

Some of the areas affected include impact on academic achievement, particularly handwriting, spelling and mathematics (Losse et al, 1991) and children with DCD are much less likely to achieve five or more GCSEs (Harrowell et al., 2018). Handwriting problems are frequently highlighted in children with DCD. They are reported to produce less legible writing (Smits-Engelsman et al., 2001) and fewer letters when copying (Prunty, Barnett,

Wilmut & Plumb, 2013). Leisure is also affected (Zwicker et al., 2012), particularly difficult for boys participating in team sports (Poulson et al., 2007) or being left out of physical activities (Zwicker et al., 2018). Children with DCD also experience impairment in the ability to undertake self-care activities, which can include doing up fastenings, cutlery and utensil use (Zwicker et al., 2018), grooming activities such as cutting nails, or brushing and styling hair, for example (Stephenson & Chesson, 2008; Missiuna et al. 2007; Wang, et al., 2009). These every day struggles can negatively impact on quality of life for the child with DCD (Zwicker et al., 2013 & 2018). Indeed, Cantell & Kooistra (2002) cautiously summed up potential long-term prognosis most likely ascribed to DCD as 'withdrawal, passivity and isolation'. Undoubtedly, the implications are that DCD should be assessed and appropriate intervention started early in order to avoid some of the serious negative consequences.

2.3.1 Use of the ICF to describe problems in DCD

The International Classification of Functioning, Disability and Health (ICF) WHO (2001) is useful when considering where the problem lies and where to target intervention as it characterizes differences on three levels: 1) body structure or functions (impairments), 2) activities or whole body movements (activity limitations) and 3) involvement in life situations (participation). For example, a child with DCD might encounter difficulties at all three levels in the following ways: 1) body structure – impairment (poor balance and incoordination), 2) activity- activity limitation (unable to ride a bike) and 3) participation - participation restrictions (unable to play out with friends on bikes and so misses future experiences). Missiuna, Rivard & Bartlett (2006) reviewed assessment and intervention practice for children with DCD using the ICF and found tools that measured extents of impairment or activity limitation were useful for identifying children with DCD and determining optimal type of intervention, whereas evaluative tools measuring activities or participation (not impairments) were more useful for determining change over time. Improvement in functional tasks tends to be environment–specific and participation or engagement in activities directly impacts the quality of life of the individual (Missiuna, Rivard &

Bartlett, 2006). Therefore, evaluative measures that capture this information are more useful to evaluate participation levels and efficacy of intervention, whereas impairment measures are useful to quantify any change in the extent of impairment. This is also important in research, as there is a dearth of information in the field of DCD about how the severity of motor impairment, or indeed how specific impairments, impact specifically on participation. The intervention work reported by Dunford (2011) demonstrated that improved function could occur without improvement in impairment scores. Thus by examining the interaction between a child's strengths and weaknesses and particular environmental factors it can help in understanding the complexity of some of these factors in DCD, such as presence or absence of co-occurring conditions (Green et al, 2008).

2.3.2 Physical activity limitations and withdrawal from physical activity

Of particular concern for children with DCD are the long-term effects of physical activity limitation and withdrawal from physical activity (PA). Reduced physical activity may lead to risk of secondary problems (Missiuna, Rivard & Bartlett, 2006) such as decreased strength and fitness (Schoemaker & Kalverboer, 1994) and obesity, although empirical results are still equivocal on obesity (Cairney, 2015). Rivilis et al. (2011) conducted a systematic review to synthesize data on fitness and PA in children with DCD and although body composition, cardiorespiratory fitness, strength, endurance, PA and anaerobic capacity had all been negatively associated with poor motor proficiency, methodological challenges led to mixed and inconclusive results. Clearly children with poor motor competence will be at greater risk of hypo activity and potentially at greater risk of later cardiovascular disease. However, Rivalis et al. (2011) concluded that participation in PA is influenced by a multitude of factors, such as self-perception, social and environmental pressures. Therefore a better understanding of the factors, including environmental contexts that influence children's participation in PA, is required for research and appropriate intervention design.

2.4 Diagnosis of DCD

DCD is diagnosed by behavioural characteristics, as there are no known biomarkers for DCD. Therefore clear diagnostic criteria are vital, as the danger of it becoming an umbrella term for the myriad of symptoms with which it is associated is evident. Baird (2013) considers this reliance solely on observation of surface features of behaviour contentious, since diagnostic systems have moved beyond medical classification and are used to set eligibility criteria for services and benefits.

Two classification systems exist for DCD for this reason and these have gone through several changes over the last three decades. They are the World Health Organisation (WHO) International Classification of Diseases and related Health Problems (ICD-10: WHO, 1992, 1993) and the American Psychiatric Association (APA) Diagnostic and Statistical Manual for Mental Disorders (DSM- III-R (APA, 1987); DSM-IV (APA, 1994); DSM-IV-TR (APA, 2000) and DSM-5 (APA, 2013). The additional credibility this gives the disorder has been noted by Chambers et al. (2005) and probably accounts for the exponential rise in research interest in the condition in the last three decades.

However, despite the two systems having common characteristics, there are significant differences in the terminology and criteria between the two. For example, even the titles differ, in ICD-10 (WHO, 1992, 1993) the disorder is known as “specific developmental disorder of motor function” while in DSM-III (1987), DSM-IV (1995), DSM-IV-TR (APA, 2000) and DSM 5(APA, 2013) it is referred to as “developmental coordination disorder”. Although there are currently no medical tests for the diagnosis of DCD, the classification systems ICD-10 and DSM-IV offer specific inclusion and exclusion criteria that must be met to achieve a diagnosis of DCD. Each system has four criteria, but they contain subtle differences. ICD-10 will be discussed first and compared to DSM IV. Then the changes leading to DSM 5 will be discussed in relation to subsequent empirical evidence and expert consensus agreement. ICD-11 is currently under review and will not be implemented until 2022 and so will not be discussed here.

2.4.1 ICD -10 (WHO, 1993)

Table 2.1 ICD-10 (WHO, 1993)

Criterion A	The score on a standardized test of fine or gross motor coordination is at least 2 standard deviations below the expected level for a child's chronological age.
Criterion B	The disturbance described in criterion A significantly interferes with academic achievement or with activities of daily living.
Criterion C	There is no diagnosable neurological disorder
Criterion D	Most commonly used exclusion clause. IQ is below 70 on an individually administered standardized test.

Thus in ICD-10 (WHO, 1993) the first two criteria are inclusion criteria. Criterion A acknowledges the developmental aspect and relates motor function to chronological age and also states a specific level of impairment in either fine or gross motor coordination at least 2 standard deviations below the expected level on a standardized test. This assumes that all standardized tests are equal and measure exactly the same constructs, something that will be challenged and discussed later. Criterion B is the same in both classification systems as they both agree that there must be significant interference with academic achievement and everyday activities, although these are not specified.

The remaining criteria are exclusionary; criterion C excludes any neurological disorder and criterion D excludes intelligence quotient (IQ) below 70, as motor incoordination is known to be associated with both neurological disorders and lower IQ.

Let us turn our attention to DSM-IV, as this too has four criteria, two inclusionary and two exclusionary but they differ in the following ways.

2.4.2 DSM IV (APA 1995, 2000)

DSM IV (APA, 1995) & DSM IV- TR (APA, 2000)

Table 2.2 DSM IV (APA, 1995, p56)

Criterion A	Performance in daily activities that require motor coordination is substantially below that expected given the person's chronological age and measured intelligence. This may manifest in marked delays in achieving motor milestones (e.g. walking, crawling, sitting), dropping things, "clumsiness", poor performance in sports, or poor handwriting.
Criterion B	The disturbance in criterion A significantly interferes with academic achievement or activities of daily living.
Criterion C	The disturbance is not due to a general medical condition (e.g cerebral palsy, hemiplegia, or muscular dystrophy) and does not meet existing criteria for Pervasive Developmental Disorder.
Criterion D	If Mental Retardation is present, the motor difficulties are in excess of those usually associated with it.

DCD is classified in DSM-IV under 'disorders usually first diagnosed in infancy, childhood or adolescence' as a 'motor skills disorder' (APA, 1995). Criterion A here also acknowledges the developmental aspect and that manifestations of poor coordination vary with age, and should be below that expected for chronological age, but also mentions measured intelligence. Significantly, no specific mention is made about standardized testing or of level of motor impairment required for diagnosis, or of level of intelligence.

Criterion B is the same as ICD-10 and states that there must be significant interference in academic achievement or daily activities, but again does not specify which ones. The exclusionary criteria C and D are significantly different from those in ICD-10. Criterion C is broadened to exclude a general medical condition, rather than just neurological disorders, and specifically excludes

Pervasive Developmental Disorder. Criterion D allows for a diagnosis of Mental Retardation, but unlike ICD-10, does not specify an IQ level and furthermore states that the motor difficulties must be in excess of those usually associated with it. Thus DSM-IV acknowledges the motor difficulties associated with lower IQ, but importantly does not exclude these children from a diagnosis of DCD.

The diagnostic criteria in DSM-IV can be interpreted as slightly more inclusive than those in ICD-10 and in addition allows for a dual diagnosis and will be discussed in more detail later. The DSM-IV definition also acknowledges that there are other disorders commonly associated with DCD that may include Phonological Disorder, Expressive Language Disorder, and Mixed Expressive Language Disorder (APA, 1995). This introduces the notion of co-occurrence of developmental disorders and DCD, something that has precipitated much debate amongst researchers, such as Hill (2001), Kaplan et al. (1998; 2001; 2006) and Green and Baird (2005) and will be discussed later. Furthermore, it mentions that the prevalence of DCD can be 5% of children aged 5-11 years and that the course can be variable (APA, 1995). However, subsequent empirical evidence from population studies by Wright & Sugden (1996) and Lingam et al. (2009) have raised some important questions about classification methods which will also be discussed later. Thus, under DSM-IV diagnostic classification, dual diagnoses may be given if ADHD is present, but not if Pervasive Developmental Disorder is present.

2.4.3 Clarification and the need for consensus

With two parallel classification systems being used to diagnose children, researchers began to question whether they were investigating the same type of disorder and could legitimately compare studies. One criticism was that the classification system had developed without any real empirical evidence (see Henderson & Barnett, 1998 for a discussion). This led to the development of consensus statements, agreed by the research community in the field of DCD.

2.4.3.1 The London consensus statement (Fox & Polatajko, 1994)

The first of which was the London consensus statement (Fox & Polatajko, 1994) in which there was an agreement to adopt DSM-IV (APA, 1994) terminology and classification. Furthermore, some important assumptions based on empirical evidence were made explicit. For example, DCD was accepted as a chronic or permanent condition rather than something children outgrew, that there were poorly understood multifactorial aetiological factors, with evidence for contributory effects from gestational events and heredity influences with the probable existence of subtypes of DCD (Fox & Polatajko, 1994). The importance of a comprehensive diagnostic process was discussed in order to distinguish DCD from other diseases or progressive neurological disorders and sufficient consideration given to a child's unique experiences of their family, their environment and factors such as genetic endowment and their temperament. Secondary characteristics including self-esteem, motor planning and coping strategies were also highlighted as important considerations that affect motor performance (Fox & Polatajko, 1994). This would involve a comprehensive assessment process and individualized intervention focused on improving functional performance.

Despite the aim of this consensus to facilitate more specific research into DCD by stipulating inclusion and exclusion criteria, a criticism was that few researchers made explicit their adherence to each of the specified criteria (Geuze et al., 2001). Later, the Leeds consensus (Sugden et al., 2006) built on the previous work of the London consensus and debated issues that had arisen in research in the intervening years.

2.4.3.2 The Leeds Consensus (Sugden et al, 2006)

Several themes had emerged from research into DCD, which the Leeds consensus addressed in relation to each criterion from DSM-IV. The themes include impact of motor impairment on functional performance, the diverse presentation of symptoms with a variable course, the importance of a child's

context and movement experience and the frequent co-occurrence of DCD with other developmental conditions.

DCD is described as an idiopathic condition with a varying, but significant impact throughout the lifespan recognized across culture, race, socio-economic status and gender. Although the onset is apparent in the early years, it does not recommend diagnosis of DCD before 5 years of age. This is also echoed by clinical guidelines Blank et al. (2012), which are currently being updated.

The persistent nature of DCD is also given emphasis, which draws on evidence from longitudinal research (Losse et al, 1991; Geuze & Borger, 1993; Rasmussen & Gillberg, 2000; Cantell et al., 2003). These acknowledge that the long-term prognosis can be variable, with a small proportion improving, whilst others continue to have motor difficulties into adulthood. However this poses important questions about identification and measurement issues in DCD, as we need to be sure that like children are being compared. Research needs to be explicit about how the criteria for diagnosis have been assessed and met, and indeed which measurements to take to establish change over time. This is important and will be discussed in detail in chapter four. The consensus statement also acknowledges potential serious negative outcomes, such as DCD being often accompanied by educational, medical and psychiatric problems (Sugden et al, 2006). This serves to highlight the need to identify which children are likely to be most at risk so that intervention may start earlier to avoid some of the secondary consequences. Thus the difficulties caused by DCD are acknowledged to start in early childhood and are likely to continue throughout the individual's life, although the nature of the difficulties may change over time.

Another significant factor in the Leeds consensus is the need to account for the importance of the individual's context i.e. their learning environment and learning experience. It states, "without adequate support and/or specific intervention within the family, school and work environments, an individual with DCD will be placed at a significant disadvantage" (Sugden et al., 2006, p5).

Thus emphasis is shifted from a within-child deficit to consider the wider social and environmental influence, which is more in line with knowledge about the acquisition of skills and learning (see Bronfenbrenner, 1979). Thus child–environment interactions are acknowledged as an important part of child development and for the acquisition of motor skills, which will also need due consideration before giving a diagnosis of DCD.

Other significant differences in the Leeds consensus relate to criteria C and D and co-occurring conditions. Evidence suggests DCD is a unique and separate neurodevelopmental disorder, which can and does co-occur with one or more neurodevelopmental disorders, commonly Attention deficit hyperactivity disorder (ADHD), Autistic spectrum disorder (ASD), and developmental Dyslexia. It therefore suggests that it is "inappropriate to exclude possibility of dual diagnosis of DCD and Pervasive developmental disorder (PDD), and both should be given if appropriate" (Sugden et al, 2006, p6). This is a clear amendment to DSM-IV-TR (2000), which excludes DCD if PDD is diagnosed. Furthermore, studies such as those by Peters & Henderson (2008) and Green et al. (2008) have since provided evidence for 'pure' DCD despite the existence of evidence for many children who meet the diagnostic criteria for more than one developmental disorder (Pearsall-Jones, Piek & Levy, 2010; Lingam et al, 2010; Hill, 1998; Hill, 2001; Green & Baird, 2005; Gillberg, 2000).

This adds an additional layer of complexity to the assessment and identification of problems for children with DCD and poses further questions about trajectories and functional outcomes for the children with additional diagnoses. Will children with DCD and one or more additional developmental conditions have a worse prognosis? Work using latent class analysis on questionnaire data about developmental disorders by Martin, Piek et al. (2010) indicated that the likelihood of comorbidity increased with symptom severity and is consistent with the findings from Kaplan et al. (2006). Thus it would appear to indicate that general screening for other developmental disorders is important if a child meets the criteria for one disorder.

2.4.3.3 Specific criteria from the Leeds consensus with potential impact on research

Exclusion criteria: The Leeds consensus is clear, however, about exclusion criteria. Specifically that known medical conditions (cerebral palsy (CP), hemiplegia, muscular dystrophy (MD)) should exclude diagnosis of DCD and that IQ level cut off is clearly stated, a child with IQ below 70 (either measured or presumed) should not be given diagnosis of DCD because of the higher prevalence of motor disorders. This is in contrast to DSM-IV-TR (2000), which does not state an IQ level. This should help to narrow the focus for clinical and research interest in DCD. However, potential issues are highlighted with each theme.

Assessment and cut-off point: Another clear directive from the Leeds consensus regards assessment, because of the influence the type of assessment has both on goals and on the process of intervention. Specifically it stipulates that in order to meet criterion A, an "individual, culturally appropriate assessment, norm referenced test of general motor competence for criterion A with recommended cut off level at 5th percentile for research and clinical settings" should be used (Sugden et al, 2006, p6). However much of the DCD research literature has included children up to the 15th percentile and has made no distinction between the children at the 5th percentile.

Criterion B suggests that the link between academic achievement and poor motor coordination is complex. It makes more explicit recommendations about assessment of daily living and suggests it should include culturally relevant self-care, leisure and schoolwork (including tool use, P.E. and handwriting). Importantly, it suggests that the views of child, parents, teachers and relevant others should also be taken into account. This is a significant acknowledgement of the importance of child and family centred care, but it is expensive and lengthy to gain views of all stakeholders in research and so few studies have included this important information.

Criterion C: it recommends a conventional neurological examination to rule out major neurological conditions. However, it is often rare to find input for a medical examination in the research literature.

IQ cut-off point: Criterion D suggests that ideally a measure of IQ should be obtained, but where not feasible, a teacher's opinion or national test data are acceptable to establish a general level of intellectual ability and below IQ 70 should not be given diagnosis of DCD. However, lower IQ level is more commonly encountered in a clinical setting and so this may be problematic in practice. Research tackling issues found in clinical populations may also be more useful.

Thus we can see that by following explicit recommendations potential ambiguity can be removed from research populations thereby ensuring easier comparison across future research. However, the issues highlighted above warrant some investigation. Specifically, there is a dearth of evidence whether the children with different severities of DCD progress differently and the debate continues over different cut-off points for motor assessment.

Finally, it addresses skill generalization and states that a number of individuals can contribute to enhance generalization and application in the context of everyday life. It should take account of family circumstances, be evidence-based and grounded in theories and nature of learning, and enhance environmental conditions that support skill acquisition. This supports current thinking in the World Health Organization International Classification of Functioning, Disability and Health ICF, (WHO, 2001) which acknowledges the social model of disability and recognizes the importance of person–environment interaction in any assessment of function. Indeed, as Green et al. (2008) and Dunford (2011) point out, it is not known whether it is the children who continue to have low motor ability who will go on to have the worst functional outcomes. Poor motor coordination per se may not be the most important factor in impaired function, thus it is vital for future research to examine the interplay of

additional factors, such as the number and type of additional developmental conditions, the child's IQ, the child's context, movement experience and preferences.

This calls for innovative methods of research to capture and record this data for analysis. Case study research employing qualitative methods has started to appear in the DCD literature (Peters & Henderson, 2008; Summers, Larkin & Dewey, 2008; Mandich, Polatajko & Rodger, 2003; Missiuna, Moll, Law, King & King, 2006; Missiuna, Moll, King, King, Law, 2007; Missiuna, King, Stewart, Macdonald, 2008) and is starting to throw light on some of these areas.

2.4.4 DSM 5 (APA, 2013)

DSM-5 criteria are those currently used to diagnose DCD. These have incorporated updated research evidence and current understanding of the nature of DCD. It changed the criteria slightly from DSM IV (see table 2.3).

The important addition in criterion A in DSM 5 now emphasizes not just the delay in motor skill but also includes the acquisition of motor skills, even when given adequate opportunity for their learning and practice and that this extends to ongoing problems in the execution of the motor skills already learned (Missiuna, 2015). Clearly this has implications for intervention, as Schoemaker & Smits-Engelsman, (2015) note, in so much as repetition alone will not lead to significant improvement. However, Henderson & Geuze (2015) caution that changes in criteria introduced in DSM-5 require careful consideration, pointing out the introduction of 'opportunity for skill acquisition and use' in criterion A seems reasonable, until one considers how it may be evaluated. A certain amount of clinical judgment will still be required of the assessor.

Table 2.3 DSM5 criteria (APA, 2013, p74)

Criterion	Diagnostic features
A	Acquisition & execution of coordinated motor skills is substantially below that expected given individual's chronological age & opportunity for skill learning and use.
B	The motor skill deficits in A significantly & persistently interfere with activities of daily living appropriate to chronological age and impacts on academic/school productivity, prevocational & vocational activities, leisure & play
C	Onset of symptoms is in the early developmental period
D	The motor skills deficits are not better explained by intellectual disability or visual impairment and are not attributable to a neurological condition affecting movement (cerebral palsy, muscular dystrophy, degenerative disorder)

Criterion B now acknowledges the far-reaching impact of motor difficulties on leisure and play in addition to those already noted in self-care and school activities. DSM-5 now focuses on the child's engagement within the community in addition to the family and home environment (Missiuna, 2015). Furthermore, by noting a persistent interference with pre-vocational and vocational activities, as well as leisure activities, it acknowledges DCD as a serious chronic condition across the life span.

In addition, criterion C notes that the condition is present from birth and that the onset appears in the early developmental period indicates that DCD is considered a neurodevelopmental condition (Missiuna, 2015; Wilson, Smits-Engelsman et al., 2017).

Importantly criterion D addresses co-morbidity and dual diagnosis, opening the possibility of children with diagnosis of ASD also having a diagnosis of DCD. The notion of a diagnosis of DCD despite lower IQ is also possible, unless the

motor impairment is better explained by the intellectual delay, rather than as a co-occurrence of DCD. Furthermore, Williams et al. (2014) argue that now, as criteria D is more specific than in previous iterations, there is no reason that preterm birth should preclude a diagnosis of DCD unless CP is diagnosed.

2.4.4.1 Commentary on DSM-5

Although the present iteration for DCD identification and diagnosis is clearer in DSM-5, some interesting challenges remain. Baird (2013) highlights some concerns regarding DSM5 for the diagnosis of DCD. The first concerns how developmental disorders are now viewed. Many disorders are now considered dimensional that were once considered categorical, which creates challenges for any classification system. The second concerns the reliability, validity and utility of any classification system. Baird (2013) points out that these are paramount for three reasons; they set criteria for diagnosis and research, they function as a clinical tool and they are the basis for remuneration in some countries. The third challenge concerns change over time, Baird (2013) notes that many of the children and young people encountered in a clinical setting frequently do not meet the criteria for certain disorders and often change from one diagnosis to another as they grow older. This can create problems for categorizing and comparing groups of children when tracking them in longitudinal research, as they are likely to change group over time. The fourth concerns consideration of risk factors. Current knowledge on neurodevelopmental disorders indicates a complex mix of genetic and non-genetic risk factors (Baird, 2013), although the cause of DCD remains elusive. DSM-5 tries to account for this as it allows account of the uniqueness of the individual by specifying the pattern of onset, course and associated descriptive features (e.g. intellectual ability). The fifth concerns consideration of the symptom severity in relation to the impairment of everyday function. Baird (2013) suggests that by adopting a quantitative approach to symptom severity, dimensions will be recognized, and use of the framework of ICF will consider individual strengths and needs as well as the enablers and barriers in the environment.

So we see that the identification of DCD is complex. Over time the criteria for definition, diagnosis and classification have become more specific as more empirical evidence becomes available and an account of individual and environmental factors now form a central part of the process.

However, symptom severity has been under represented in research. In particular the severity of the motor impairment, whether mild, moderate or severe is important as this could have an impact on the reported prevalence rates, the perception of the problem by services and on the reported outcomes. An example of this is the group of children who are classified as having moderate motor impairment and are "at risk" of DCD and there is some contention over their importance. For example, the international clinical practice guidelines include this group in their classification, whereas the Leeds consensus does not. Nonetheless, the scrutiny of research is important, yet research serves little purpose unless the findings can be applied to practice and, in the case of DCD, inform identification and intervention. A group of international experts examined recent research on DCD to produce the clinical practice guidelines for DCD.

2.4.5 Clinical practice guidelines: EACD (2012)

The European Academy for Childhood Disability (EACD) developed the guidelines for DCD (CPG-DCD) led by Blank et al. (2012). They are currently under review for update. They apply to children "with long-standing, non-progressive problems of specific motor skill performance, not attributable to any other medical or psychosocial condition" (Blank et al, 2012, p59). One of the most striking differences between these and the Leeds consensus relate to the percentile cut-off used for diagnosis. The European EACD recommendations (Blank et al, 2012) state that limited sensitivity in the presently available motor test battery makes the conservative 15th centile cut-off safer. Furthermore, they suggest that any area-specific deficits that would be relevant to ADL (e.g. balance or dexterity) would be missed if only using the 5th centile (Blank et al,

2012). Moreover, they note that as reasonably good agreement exists between most motor measures using the 15th centile they suggest that it is "plausible to use a cut-off level of 15th centile in addition to criteria II and III" (Blank et al, 2012, p73) in order to be able to give children adequate support. It is possible too that by allowing a cut-off of 15th percentile insurance companies will permit treatment for children in this at-risk range.

Whilst this is relevant clinically, an important distinction between the different requirements of clinical and research settings should be noted here in order to properly classify the children. Blank and colleagues (2012) use the term 'moderate DCD (SDDMF)' to describe children scoring between the 5 and 15th centile on a motor test battery, whereas others have used the term 'at risk of DCD' to describe this group (for example Johnson & Wade, 2009). Correct classification of children for research assumes a much greater significance when considering patterns of dysfunction and possible trajectories as the children with moderate DCD may constitute a different group from those with severe DCD. However, this will require first classifying and then analysing the results from each group over time by use of longitudinal study design.

2.5 Chapter summary

DCD is complex, with a myriad of motor and non-motor symptoms, many of which can have serious long-term implications if left unrecognized. DCD has been the focus of a great deal of research over the last 30 years that has contributed significantly to the body of knowledge. However, identification and diagnosis are not straightforward and several issues remain with the interpretation of diagnostic criteria, despite the consensus agreements and international guidelines. However, since DCD is primarily a disorder of motor development and the acquisition of motor skills and they are core features of the condition, it is prudent to consider underlying motor theory. An understanding of motor development is central to the understanding of DCD and so the next chapter will outline current interpretation of the theories of

motor development and of motor skill acquisition and relate these to the research that has informed our current understanding of DCD.

CHAPTER 3 DEVELOPMENT OF MOTOR CONTROL AND MOTOR LEARNING

The previous chapter outlined DCD as a disorder of motor development and this chapter begins by exploring the nature of child development and the development of motor control. The first part of the chapter explains what is known about motor development from a theoretical perspective, while the second part of the chapter explains current understanding of motor learning and skill acquisition. Motor development and motor learning are intrinsically linked, as development is age related and experience dependent, so generally speaking, motor control improves with age and experience and as we learn more we develop more. However, this is not necessarily the case for motor control in children with DCD. Brief overviews of some of the theories of motor development are discussed, in particular the emerging change in emphasis of the importance of the role of the environment and active movement experience in motor development theory. The capture of the nature of change in motor development is discussed from a dynamical systems perspective and the concept of motor variability is explored and related to functional participation in physical activity for essential movement experience. Some additional constraints with respect to motor learning and participation are discussed, such as self–perception and parental support along with the role of practice and the role of the environment are also considered when examining participation in physical activity (PA). The concepts are related to children with DCD in order to explore why they appear to participate less in PA than typically developing children.

3.1 Defining motor development

There are a number of definitions of motor development that contribute to our understanding of the term. Adolph, Weise & Marin (2003, p134) describe it as “changes in children’s ability to control body movements from an infants first

spontaneous waving and kicking movements to the adaptive control of reaching to locomotion and complex sports skills." Sugden and Wade (2013) succinctly define it as adaptive change towards competence. Both definitions emphasize change and adaptation and these concepts will be explored within the discussion of some of the theories that have shaped our understanding of motor development. More recently Adolph (2018, p2) has broadened the scope and suggests that motor development refers to "improvements and decrements in motor skill over the life span and the processes that underlie these changes" and has identified five underlying principles. The principles will be better understood in light of the theories of motor development and therefore will be visited after a discussion of the main theories.

3.2 The nature of child development

The term development refers to the process by which an organism grows and changes through its life span, but the most dramatic changes in human development take place during pre-natal development, infancy and childhood (Smith, Cowie & Blades, 2003). Generally developmental processes have been related to age. However, an important conceptualization of development considers the ecology of development, that is studying 'development in context' and Urie Bronfenbrenner proposed a model with which to do this. He described human development as the product of interaction between the growing human and its environment and an evolving process of interaction through which the behaviour of the child is instigated, sustained and developed (Bronfenbrenner, 1979). From this perspective, the process of development is bi-directional with both the child and the setting in which the child finds itself influencing the progress. The environment considered relevant to developmental process is not limited to an immediate setting (i.e. face to face interaction), but encompasses interconnections between settings (e.g. roles, inter-personal interactions) and external influences (e.g. cultural beliefs and practices). Bronfenbrenner (1979) conceived the ecological environment as a nested arrangement of concentric structures, referred to as micro-, meso-, exo and macrosystems to explain these settings. Let us consider how motor control develops, but first clarify some terms.

3.3 Definitions: motor ability, motor skill

Almost every aspect of daily life and human interaction involves movement. This is true throughout the life span, from babies to adults, and facilitates active participation in necessary activities and social interaction. Movement can be described as the displacement of body parts and analysed as body movements or intended functions (Keogh & Sugden, 1985, p7). However, the context in which it takes place is important and concerned with the interplay of the mover's intent and function. The neuromuscular system is responsible for contracting muscles and producing movement, and movement is the observable behaviour (Keogh & Sugden, 1985, p8). However, the control of movement becomes more complicated when objects and other people are involved, as the movements are situation specific (Sugden and Wade, 2013). As typical children develop their motor control becomes more accurate and their movements more skilful.

The term ability is defined as the inherited, relatively enduring, stable trait of the individual, thought of as 'the hardware' (Schmidt & Wrisberg, 2000), and is used when referring to a capability or aptitude that an individual brings to performance situations (Sugden & Wade, 2013). Abilities are possibly genetically determined and underpin numerous skills, but are not easily influenced by practice. Schmidt and Wrisberg (2000) propose that skills, on the other hand, are chiefly developed by practice and experience. It is important to differentiate between skill and ability, particularly in atypical development and understand to what degree ability is a limiting factor and whether intervention should target abilities or skills (Sugden & Wade, 2013). It may be that children with DCD have deficits in both.

However, Burton & Miller (1998) refer to the low correlations between different motor skills and suggest that there is little evidence that motor abilities exist, however this remains contentious in sports and music (as high correlations will only occur where there are common features e.g. tennis and squash). They suggest that the term abilities can be interpreted to refer to a person's potential

movement competencies, as opposed to their actual movement performances, and that the results of an assessment procedure only indicate what a person did, not what they could do in other circumstances (Burton & Miller, 1998). Clearly this has important implications when planning intervention, and Sugden & Wade (2013) advise that deciding what to measure is of paramount importance. Equally, the same could be said about measurement decisions in research into the motor problems of DCD. However, without a sound theoretical base from which to make these decisions the measurements are of little value.

Therefore, in order to more fully understand DCD, it is helpful to consider some underlying theoretical assumptions that have influenced our understanding of motor development and in turn have influenced research paradigms through which DCD has been investigated.

3.4 Motor development theories

3.4.1 Hierarchical neuro-maturational theory

In the mid 1900s motor development was considered to be a pre-determined gradual unfolding of patterns in the nervous system. Observational work by Gesell and Amatruda, Piaget and McGraw favoured the viewpoint that motor development was driven by cerebral maturation not experience. Gesell's work was heavily influenced by that of Coghill, an early behavioural embryologist, who studied the salamander and found correlations between changes in their movement pattern and corresponding changes in their nervous systems. This led Gesell to conclude that development was biologically driven as an orderly genetic sequence (Gesell, 1933). This viewpoint left virtually no place for the role of interaction with the environment in motor development (Hadders-Algra, 2000). The notion that a genetically determined sequence followed general developmental rules, such as cephalo-caudal and proximal to distal development, predominated clinical reasoning and led to 'developmental

diagnosis', which consisted of series of tests for the assessment of developmental milestones (Hadders-Algra, 2000).

This neuro-maturational approach to motor development asserted that motor milestones were reached at specific points in time as a direct result of the specific order of development in the central nervous system (CNS). The idea was that predetermined patterns of movement evolved as cortical control took over from lower brain stem and spinal reflexes (Sugden & Soucie, 2017). Evidence from observation of the emergence of motor milestones, such as standing and walking, in the absence of movement practice was thought to support this hypothesis. Examples such as McGraw's study of the twins Johnny and Jimmy (McGraw, 1935), where Johnny was confined to his crib for most of the day and Jimmy was given motor practice, yet both attained their motor milestones such as crawling and walking at identical times.

Although motor development is now thought to be more complex than this, detailed studies of infant motor development using photographs, movies and direct observation of movement by developmentalists such as Gesell, Shirley and McGraw have provided a great legacy of methodology for the systematic study of motor development (Thelen, 2000). They paved the way for close observation, including empirical data from measurements, taken over time from the same children. For example, Shirley (1931) studied the parameters of gait development by oiling the feet of infant and toddlers, allowing them to walk on paper and taking multiple measurements. Gesell established a vast data set of developmental norms for motor milestones by repeated testing of large numbers of the same children with standardized tests and many form the basis of tests still in current use, such as Baley Scales of Infant Development the Denver Developmental Screening test (Thelen, 2000). Both Gesell and McGraw studied twins to explore the contributions of genes and the environment to motor development and both agreed that cortical readiness was necessary to improve function, giving support in their view, to the primacy of maturation in motor development (Thelen, 2000).

Although ideas about motor development have moved on, the empirical work on motor milestones laid the foundation for contemporary practice. For example, delayed motor milestones are often used a marker for atypical motor development, such as cerebral palsy, where a lesion in the motor cortex directly impacts motor control. Children with DCD are also reported to have delayed motor milestones and inclusion of this as one of the criteria for diagnosis is recommended (Blank et al., 2012, p63 recommendation 2). Perhaps indicating that DCD is viewed as involving problems or differences in the CNS. Wilson et al., (2017) support this view following their systematic review of research including neuroimaging data. This led them to conclude sufficient evidence exists to support the hypothesis that children with DCD have differences in brain structure and function to typically developing children. However, Sugden (2018) suggests that current diagnostic criteria for DCD, as defined by DSM-5, do not involve atypical neurological substrates. Moreover, most of the existing neuroimaging studies have been carried out with relatively small sample sizes and this raises questions about how representative the samples are of the DCD population. Thus the tension in research can only be resolved with more studies and representative samples.

Another consideration is the acknowledgement that there are wider influences on the development of motor control. Wade & Kazeck (2018) suggest the underlying causes of poor motor control in DCD is more complex than problems in the CNS and favour an ecological approach involving task and environmental constraints, rather than use assumptions of brain mechanisms ‘processing’ information.

Although research in the field of DCD is rapidly expanding, it is difficult to draw conclusions about causal influences of the motor difficulties without understanding the theoretical position from which they have been investigated. Many studies in DCD have drawn heavily from IP theory, where the brain and central nervous system (CNS) are viewed as the controller of the motor system.

3.4.2 Information processing theory

Information processing theory was derived from system analysis work used in communication systems, proposed by Shannon and Weaver (1949), and applied to behavioural systems in social sciences. The Shannon and Weaver model (1949) encompassed an information source, transmitter, signal, channel, receiver and destination and any interference or distortion in the signal was referred to as 'noise'. This theory has been so influential in motor development because psychologists compared human processing to computer processing and used the mathematical basis of information theory to make quantitative predictions about behaviour (Keogh & Sugden, 1985). Central to information processing theory is the assumption that information from the environment (e.g. visual, kinaesthestic, auditory, tactile etc.) requires interpretation by an internal mechanism in order to assign meaning and generate an appropriate response (Sugden & Wade, 2013). The brain is often depicted as analogous to a computer, where the input of sensory information is processed and triggers an appropriate output motor response. Sensory information entering the processing system is thought to be held in a working memory store so that it can be used to generate a plan of action, often referred to as a programme, and governs variables such as timing, force and spatial characteristics that may influence the movement outcome (Sugden & Soucie, 2017). This theory has given rise to a system of measurement and has had a huge impact on the way that processing has been investigated.

Adam's (1971) closed loop theory was highly influential in understanding skilled motor performance from an information processing stance and proposed that there were two states of memory, the memory trace and the perceptual trace. The memory trace was thought to initiate movement and influence choice of direction based on knowledge of results (KR) and through practice. Whereas, the perceptual trace (analogous to recognition memory in verbal tasks), thought to be responsible for guiding the limb to the correct location, and formed from past experience with feedback from earlier responses, is compared to incoming sensory feedback to detect errors and make necessary adjustments (Schmidt,

1975). Schmidt (1975) proposed that Adam's ideas were popular as they were testable, he had operational definitions for his constructs and suggested experimental variables, however, a criticism was that his theory could not explain generalization to rapid responses.

Schmidt addressed this with another model based on information processing theory. He proposed his schema theory (1975) to explain how humans execute rapid skilled body actions without conscious control. He suggested that sensory information modified a set of restructured movement commands, known as the motor programme, which defined and shaped the action produced (Schmidt & Wrisberg, 2000) based on a control system known as the open loop system. Input is delivered, processed and an action chosen, instructions are then sent to the effector to carry then out and the action is completed. There are no modifications while the movement is in progress as there is no feedback in the open loop system. Schmidt & Wrisberg (2000) use the analogy of a traffic light system to describe this system, the lights regulate traffic flow at a junction by a repetitive sequence of red, amber and green lights. If an accident occurs the system will still operate the lights, even if the road is blocked, as if nothing has happened because there is no feedback. Thus this system is ineffective in the face of unpredicted changes, but effective as long as the circumstances surrounding the action are unchanged, such as in a stable, predictable environment (Schmidt & Wrisberg, 2000).

Both the closed and open loop theories are underpinned by the information processing theory, based on the assumptions that motor performance and skill learning requires a motor programme to organize and execute an appropriate motor response to an environmental task demand (Sugden & Wade, 2013). Geuze (2018) terms these 'black box' theories, in which perceptual information is somehow linked into motor action.

Information processing (IP) theory has been the predominant theory in cognitive psychology and the study of motor behaviour for the last half century and has

led to a vast body of research carried out using this paradigm, particularly for research in DCD (Sugden & Wade, 2013). Indeed, Wilson and colleagues undertook two reviews of studies using this paradigm (Wilson et al. 1998; Wilson et al., 2017), both of which provided evidence that children with DCD were inferior on nearly all measures of information processing than TDC, seeming to suggest support for this approach. A further recent review of studies from 2011-2016 by Adams et al., (2017) suggested reasonably strong evidence to support the internal modelling deficit hypothesis (IMD), which is another cognitive neuroscience approach based on an information processing paradigm. The IMD hypothesis suggests that the movement difficulties in DCD are caused by deficits in predictive control when planning and executing movements (Wilson et al., 2017b).

However, Wade & Kazek (2018) argue that experimental design using an IP paradigm only searches for IP explanation for the underlying motor deficits. Although the studies using the IP paradigm have contributed to our current understanding about the nature of motor problems in DCD, they have tended to use a lab based experimental design and, one could argue, lack real world validity. Moreover, Geuze (2018) cautions that current theoretical explanations of DCD lack consensus, although other theories are also contributing to our understanding of DCD.

3.4.3 Neuronal Group Selection Theory

Neuronal group selection theory (NGST), developed by Edelman (1989), states that development starts with multiple neuronal groups forming primary neuronal repertoires, the cells and gross connectivity of which are determined by genetic information (Hadders-Algra, 2000). Experiential sensory information induces modifications in the strength of the synaptic connections within and between the neuronal groups, resulting in a variable secondary repertoire. This changed connectivity within the secondary repertoire allows for a situation specific selection of neuronal groups, which form the basis for mature variable behaviour that can be adapted to environmental constraints (Hadders-Algra, 2000, p567). Hadders-Algra (2000) argues that this suggests a complex

interplay of genes and the environment and points to the importance of self-produced activity to develop optimal circuitries.

It is often found clinically that children with DCD self select to opt out of physical games and activities, possibly further restricting their self produced movement experience thus setting up a negative cycle. Geuze (2018) appears to adopt this view and suggests there are several causes for coordination problems in DCD, which may include deviant development, slower rate of learning, as well as physical and environmental constraints, some of which may be overcome in time. Future research should then incorporate an investigation of the child's motor abilities and environmental opportunities for self produced activity as the two areas have a reciprocal interaction.

3.4.4 Ecological psychology

Another theoretical perspective, ecological psychology comes from the work of Gibson (1979), which rejects the view that information has to be processed or translated by CNS in order to formulate a motor response. Central to the ecological approach is 'affordance', which is the term used to describe the reciprocal relationship between an animal and its environment (Gibson, 1979). Affordance is the resource or support offered by the environment, but the animal in turn must have the capabilities to perceive it and also to use it (Gibson, Adolph & Eppler, 1999). This implies another reciprocal relationship, of perception and action, whereby, perception provides the information for action and action produces consequences that inform perception, which allows adaptive control of action (Gibson, Adolph & Eppler, 1999).

Gibson proposed that perception is direct, so that perception and action (movement) are viewed as directly linked, as opposed to Information processing theory where indirect perception is assumed (Sugden & Wade, 2013). The coupling of perception and action both guides and constrains future action, because the individual engaging in action detects new information and is sensitive to the properties in the environment and their opportunities for action

(Sugden & Soucie, 2017). Sugden & Soucie (2017) suggest that no action can effectively occur without consideration of the person doing the action and the context in which it takes place. For example an approaching ball may afford catching, but will depend on the skill of the catcher, the speed of delivery, the size of the ball and the prevailing wind conditions if thrown outside. From this perspective the developing child is an active participant in the process that affords change in the control of movement through the repeated cycle of exploration-perception-action (Sugden & Soucie, 2017).

Experimental evidence appears to support this view, for example, adults passing through apertures, reaching for objects with limbs or tools and judging stair heights to support the notion that adults perceive affordances in task constraints and bodily requirements and can adjust their actions accordingly (Gibson, Adolph & Eppler, 1999). Children with DCD are often seen to struggle generalizing motor skills or adapting to known tasks in a different environment, perhaps indicating difficulties with perception-action coupling. This line is taken by Wade & Kazek (2018), who argue that DCD can be viewed as a deficit in perception-action coupling with reduced sensitivity to the action opportunities present in the environment and limited capacity to fit their motor abilities to the affordances present in the environment. This has been investigated using a dynamical systems approach with some promising results and will be discussed below.

3.4.5 Dynamical systems approach

Nicolai Bernstein (1967) rejected a top-down approach to motor control by suggesting that the body, which consists of hundreds of bones and joints and millions of muscle fibres, could work together in synergies, rather than the brain sending many individual messages to coordinate movement. He suggested that the brain recruited an appropriate pattern to accomplish a functional task, rather than individual muscles, and so movement was function specific not muscle specific, citing the classic example of a person’s signature remaining the same

whether signing with pen on paper or using a broomstick on a blackboard (Thelen, 2000). He therefore proposed that control of movement was not reliant on selection of specific motor programmes, but largely self-organizing (Sugden & Wade, 2013). Bernstein noted that the body has multiple degrees of freedom that have to be controlled. For example, the many joints and muscles in the arm and trunk that must be controlled in order to reach for a glass of water without spilling it. He believed that groups of muscles are constrained to act together as a unit synergistically (Shumway-Cook & Woollacott, 2001), constrained but not controlled by the CNS (Sugden & Wade, 2013). He believed there is no need for a centre issuing commands to achieve action. From this perspective, movements can emerge as a result of interacting elements without the need for motor programmes or specific commands (Shumway-Cook & Woollacott, 2001). Bernstein claimed that it was the dynamics of movement that instructed the nervous system, rather than the other way round, because the motor system also exploits the mechanical properties of limbs and the body (Thelen, 2000). This led to consideration of the contribution of biomechanics of the moving limb to the emergence of new skills, which is particularly pertinent in children, because growth and change in centres of inertia repeatedly bring new biomechanical challenges, therefore skill acquisition for a child is a continually interactive process (Thelen, 2000).

According to the dynamic approach, developing organisms are complex systems of many individual elements embedded within and open to a complex environment (Smith & Thelen, 2003, p343). This complex system can generate organized behaviour in response to constraints and opportunities in the environment. Smith & Thelen (2003) suggest that this self-organization is characterized by stable and unstable states and so development can be viewed as a series of evolving and dissolving patterns of dynamic stability in response to the solution of a problem. They use the example of a baby crawling, a means of locomotion for a baby with sufficient strength and coordination to assume weight bearing on all fours, but not sufficient strength or balance to stand upright. This is a stable behaviour for several months, but becomes destabilized when the baby learns to walk by patterns of standing and walking.

The system self organizes in response to a problem, to cross the room, later to be replaced by a more efficient manner (Smith & Thelen, 2003, p344).

3.4.5.1 A constraints based approach

Newell (1986) used a dynamical systems approach and explored factors in environmental constraints that guide motor control. Constraints are defined as 'the boundaries or features, which interact to limit the form of biological systems searching for optimal states of organization' (Davids et al, 2003, p. 247). Newell (1986) proposed a constraints based model of motor skill acquisition that took account of 1) the characteristics of the individual, such as genes, height, weight, cognitions, motivations etc. and referred to as organismistic constraints 2) environmental constraints which can be physical such as gravity, heat, light etc. or social 3) task constraints and include specific performance goals (Davids, 2010). For the first time the individual, the task and the environment were considered to be important in the emergence of motor control.

Thus the emergence of motor control and coordination arises from the self-organized movement patterns, constrained and influenced by the task, environment and the individual performers abilities (Sugden & Wade, 2013, p69). Moreover, development is reinterpreted from the Piagetian view of the child as passive stimulus-responder to Bernstein's view of the child as an active movement problem-solver (Thelen, 2000). This self-organizing open system approach permits exploration of the child's motor actions in a variety of tasks and settings and also allows explanation of changing or inconsistent results according to the context. This is particularly important in the field of DCD, as motor inconsistency is often a trademark of the motor performance of children with DCD.

3.4.5.2 The role of body size and scale

Newell & Wade (2018) develop the idea of constraints further and highlight the role of body size and scale in movement development from an ecological perspective. They suggest that change in the size and form of the body during

childhood is a major factor in the change of movement organization and its outcome in physical activities. They suggest that body scale and the timescale of its change through growth are shown to relate to the emergence and disappearance of fundamental movement skills in infancy, the perception of what an environment affords functionally for action together with the emergent pattern of movement coordination (Newell & Wade, 2018, p205). They argue that a central issue for development is the mapping of the timescale of change in physical growth to the timescale in change of acquisition of perceptual motor skills. Further, they develop the hypothesis that an imbalance in these timescales can lead to performance deficits in perceptual motor skills and cite adolescent clumsiness during the growth spurt as an example.

Visser (1998) conducted a longitudinal study to examine motor performance in relation to growth in height and weight in adolescent typically developing boys and boys with DCD. He predicted that both groups would show a decline in performance during their rapid growth spurt. However, he found both positive and negative effects from the growth spurt and differences between the TDC and boys with DCD. The TDC, for example displayed negative growth effects that included balance, estimation of distance and muscle control consistency, but the positive effects included accuracy in target aiming. However, this was not the case for the boys with DCD, who did not appear impacted by the growth spurt, yet showed wide intragroup variability. This led him to conclude that only well coordinated boys were at risk during the growth spurt (Visser, 1998, p153). This was an interesting study, and could imply that boys with DCD experienced different sensorimotor processing. However, the sample size was relatively small (DCD n=15 and TDC n=16) and pre-dated the consensus statement on diagnostic criteria for DCD, so we cannot be sure that the DCD sample would meet DSM criteria for DCD or therefore extrapolate the results wider. Nevertheless, it exposed important differences between the groups and posed the question whether TDC are sensitive to the constraints of the effect of growth, causing a temporary disruption in their perception action coupling, whereas the boys with DCD did not have the same sensitivity?

Other DCD research has tested body scaled information affordances in perception–action experiments for example, Wilmut, Du & Barnett, (2017) found differences between DCD and typically developing participants (aged 7-29 years) when asked to make visual estimates and then actually passing through an aperture. The DCD participants had difficulty with the dynamic perception-action relationship. This appears to be supported by the experiences of individuals with DCD, who often report walking into doorframes and other objects. Johnson & Wade (2009) also found differences between the judgments of action capabilities ability of children with DCD and TDC when adapting to reach during experimentally controlled constraints. Both studies add support to proposal by Wade & Kazeck (2018) to consider DCD as a deficit in the perception-action relationship. So we see, from this perspective, the unit of analysis becomes the child, the task and the context (environment) in which it takes place (Sugden & Soucie, 2017). This lends further support for future studies incorporating an ecological approach.

3.4.6 Summary of theories of motor development

We have seen that the understanding of motor development has evolved from theories at the beginning of the 1900s, viewing development as a gradual unfolding of abilities determined by maturation of the CNS at particular points in time, with a strong genetic influence. Followed by the prevalence of the so-called ‘black box’ theories that emphasize the importance the CNS for information processing and the development of schema to formulate a motor response. The emergence of a dynamic systems approach combined with ideas from ecological psychology then served to de-emphasize the role of the developing child as a passive recipient of information and suggest an active role of the child learning from the environment and their own actions. However, tensions remain between researchers who adopt different paradigms on motor development, about causal influence of motor difficulty in the field of DCD research. The cause of motor problems in DCD is still not fully understood. It may be possible that in future an ecological perspective could encompass an IP approach within the design.

Although in practice it can be hard to distinguish between motor development and motor learning, for ease of presentation they are dealt with separately in this chapter. DCD is characterized by a deficit in the acquisition of motor skills, often referred to as motor learning, so it is pertinent now to explore how have these theories have influenced understanding of motor learning.

3.5 Motor skill acquisition/motor learning

Schmidt and Wrisberg (2000) draw attention to important differences between motor performance and motor learning. They suggest that motor performance is always observable and influenced by many factors (such as fatigue, motivation and attention), whereas motor learning is an internal process that reflects the level of a person's performance capability. Thus performance may be thought of as one shot that can be influenced by temporary variables, whereas motor learning is more generic. Furthermore, they state than in order to learn a motor task, a person must engage in practice or performance attempts (Schmidt and Wrisberg, 2000, p12). Schmidt and Lee define learning as a relatively permanent increase in capacity to change behaviour brought about by practice and or experience. Sugden & Wade (2013) emphasize this change in behaviour and state that motor learning involves acquiring a set of processes that are instrumental in changing motor behaviour and echo that it is a relatively permanent state. Children with DCD encounter difficulty with motor learning and their motor performance is also likely to be impaired and so it is important to understand some of the ideas behind current understanding of motor skill acquisition.

3.5.1 Closed loop theory and the role of feedback in motor learning

We return to Adam's Closed loop theory (1971), whereby learning was considered to be facilitated by refinement through a series of perceptual-motor feedback loops, using assumptions based on information processing theory (Rosenbaum, 2010). For example, the inexperienced learner approaches a task with a crude movement and perceptual feedback indicates that the movement was not effective, so that subsequent movements are performed to

reduce the error, using a perceptual trace feedback loop. The perceptual trace is the internal reference with which to compare movement and detect error through repeated practice (Zwicker & Harris, 2009). Rosenbaum (2010) suggests, that according to closed loop theory, feedback should help people perform tasks more effectively and points to the improved performance of novice skill learners given explicit verbal feedback (called knowledge of results, KR) over the performance of those who are not told how well they have performed. However, the theory falls down when applied to complex motor skills, skill generalization and skills that can be performed when feedback is removed, but Rosenbaum (2010, p103) asserts that it 'does a good job of explaining specificity of practice'. An example of this is described by Schmidt & Wrisberg (2000, p221), who explain that practitioners can enhance development of learner's error detection by verbally drawing attention to their movement-produced feedback by asking them to estimate or describe aspects of their movement, thus helping them become sensitive to it leading to improved capability. This approach has been used with children with DCD, but has been criticized, as there is little skill generalization to other tasks.

3.5.2 Open loop or schema theory in motor learning

Schmidt (1975) proposed an open loop theory where generalized motor programmes, or schema, created from past movement patterns influence future motor performance (Zwicker & Harris, 2009). These are thought to consist of pre-programmed muscle commands, reducing the need for feedback control. They take the form of stored responses for specific movements, including information on conditions such as speed and force, in addition to information on the sensory consequences of the intended movement (Hill, 2005, p48). Rosenbaum (2010) suggested that open loop theory provides a better explanation of skill generalization and the accounting for variability and novelty of performance. Hill (2005) suggested that this evidence points to use of both open and closed loop control in skilled movement. The idea is that the general motor programme is adapted for each situation in parallel to the execution of the movement itself, implying that on-line changes can be made to existing

programmes (Hill, 2005). Wolpert et al., (1998) proposed a model involving the role of the cerebellum in inverse and forward models of the motor system, so that the body is capable of learning to produce appropriate motor commands under a variety of contexts and can switch rapidly between controllers to adapt as the context changes. These assumptions led to a line of enquiry in DCD research that proposed that the internal models (controllers) for specific motor skills might be disrupted in DCD (Mon Williams, 2005) and led some researchers to implicate the role of dysfunction in the cerebellum, which Missiuna et al. (2006) suggested had some face validity. However, the experimental design has been quite task specific with little attention paid to environmental constraints so far.

3.5.3 Ecological relevance and task constraints in a dynamic systems approach to motor learning

The constraints approach in dynamical systems was introduced earlier, but now specific comments on constraints will be addressed with respect to learning. A further analysis of some of the terms in this field of study may help with the conceptual understanding from a theoretical stance. Newell, (1991), for example, distinguished between motor learning, motor control and motor development, which he considers as related subdomains to motor skill acquisition. However, he acknowledges that the study of all three areas share considerable common theoretical ground and refers the reader to Wade & Whiting (1986) and suggests that this is also supported by theoretical developments in the understanding of perception and action (Newell, 1991).

Furthermore, Newell highlights that contemporary study of motor skill acquisition implicitly focuses on self-generated motor performance enhancement within a variety of contextual and task constraints and deemphasizes the role of instructional concepts. As a consequence of this, he suggests that, models and theories of motor skill acquisition have tended to be task and context specific and so any development of broad theoretical perspectives on the acquisition of motor skills is dependent on a general

understanding of task constraints (Newell, 1991). He critiqued the information processing approach to the understanding of motor skills acquisition, stating that largely emphasis has been on how information is processed and little emphasis has been given to what information is processed. He also states that the interest in learning from the cognitive perspective, during the 1980s, was largely orientated to so–called cognitive tasks. Thus neither of which fully addressed the understanding of motor skill acquisition, but he suggests that a synthesis of the two could be facilitated by an understanding of the influence of task constraints on motor skill learning.

Newell argues that the traditional approaches to motor skill acquisition have failed to capture many of the dynamic qualities of the stages of motor skill acquisition exhibited by novice and expert performers. "Skill is as reflection of a dynamic exploratory activity, not the stereotypical reproduction of a static representation of action" (Newell, 1991, p 233), furthering his argument for the understanding of ecologically relevant aspects of task constraints and the dynamic interaction of information and movement. This may be an important focus for our understanding of the motor skill acquisition problems faced by children with DCD.

However, Schmidt & Wrisberg (2000) argue that the most important contributor to motor learning is the act of proper physical practice and the quality of that practice is crucial, so the role of practice in motor learning in DCD is discussed below.

3.5.4 The role of practice in motor learning for DCD

We know that children with DCD do not learn by just providing them with opportunity to practice, as they have a low level of transfer from one acquired skill to the next and the acquired skills are highly contextual (Schoemaker & Smits-Engelsman, 2005). Sugden & Wade (2013) advise that practice is more formal than experience and includes variables such as how to present the tasks

(partial or whole task), the distribution of practice (e.g. blocked or random, constant or varied), the type and amount of feedback and the transfer and retention of skills (Sugden & Dunford, 2007). Therefore, the structure of practice will have added importance for children with DCD because of their difficulty in motor learning. However, the most effective method of practicing or providing instruction and feedback depends on the stage of learning of the child.

Fitts & Posner (1967) describe three stages of learning: the first is the cognitive stage, which is required to detect which movement pattern will be required to achieve the goal; the second, is the intermediate level, where the basic movement pattern is mastered but refinement is still needed and errors occur; the third stage is one of automaticity, where movement patterns can take place without conscious attention (Schoemaker & Smits-Engelsman, 2005).

Blocked practice, where an individual performs a single task repeatedly (sometimes called constant practice) is often used in the early stages of learning. Random practice, where an individual attempts several different tasks in an intermingled order, has been found to be more effective for higher rate of transfer and retention of the skill and used after the first stage of learning (Schmidt & Wrisberg, 2000). This varied practice is also thought to facilitate adaptability by developing stronger schemas (a set of rules relating to various outcomes of the individual's actions) to allow them to generalize the experience to other motor performance (Schmidt & Wrisberg, 2000).

However, this generalization, or as Hadders-Algra (2000) describes it 'adaptive variability' (where children can adapt their behaviour to specific demands of a situation), is particularly problematic for children with DCD. Neuromotor Task Training (NTT) (Schoemaker & Smits-Engelsman, 2005) is one intervention approach that has applied principles of motor learning. It is a task orientated approach to training motor skills in children with DCD, whereby skills required in daily life are taught directly and encourage active practice in ecologically relevant tasks, underpinned by dynamical systems theory (see Schoemaker &

Smits-Engelsman, 2005 for a description). The EACD guidelines (Blank et al., 2012) recommend that it may be a useful intervention for DCD, as there is some empirical evidence to support its efficacy to help the children develop the motor competency to complete functional goals. A systematic review by Preston et al. (2017) also found strong evidence to support this approach for DCD.

3.6 Assessment of motor change over time and variability in motor control

Motor development has been defined as 'adaptive change towards competence' Sugden and Wade (2013, p2), which emphasizes the transactional relationship between the individual and the environment, but change is not always represented as a smooth trajectory. Sugden & Wade (2013) argue that the diverse nature of observable behaviours associated with motor change includes variability, continuity, discontinuity, accelerations and spurts, rather than the smooth linear graph that is often portrayed. From this stance, the variability of motoric change can be explained. They contend that conventional methodological design often miss critical points of developmental change by using methodological designs such as cross-sectional or generalized longitudinal designs and so tend to represent change as linear. Perhaps by following the motor change in children with DCD more closely, the notorious intra individual and intra group differences may reveal more information about the nature of DCD.

Adolph and colleagues argue that all children's movements are variable and that intra individual variability is a signature component of motor development and of goal directed behaviour (Adolph, Cole & Vereijken, 2014). However, depending on the nature of the motor skill, some aspects of motor skill intra individual variation decreases over development, other aspects of motor skill variability continues and increases over development and for yet others, the structure of variability changes over development. This is illustrated by case examples of the research on acquisition of infant walking and concludes that

intra individual variability can refer to very different aspects of motor behaviour occurring at very different temporal and spatial sequences (see Adolph, Cole & Vereijken, 2014 for a review of the research). It is therefore important to make distinctions between the nature of the motor skills under investigation; otherwise false conclusions can be drawn.

Adolph and colleagues observe that this poses a problem for research in motor development, as studies tend to focus attention on one area to the exclusion of another. For example, in the investigation of the development of motor control, the focus is on the decrease in intra individual variability and on standardized tests and laboratory tasks where consistency is paramount. Whereas, in contrast, the investigation of the developmental of improvement in adaptability to novel conditions research tends to focus on increase in intra individual variability or continuance, in which behavioural flexibility is more important. Additionally, studies investigating developmental changes in the organization of movement tend to focus on the structure of variability in order to uncover optimal levels of predictability and complexity (Adolph et al., 2014). The picture is therefore complex and is dependent upon which elements of motor development are under scrutiny.

3.6.1 Variability and the stages of skill acquisition

In the early stages of skill acquisition intra individual variability is thought to reflect poor motor control (Deutsch & Newell, 2005; Vereijken, 2010 cited in Adolph et al., 2014) and so development involves acquiring sufficient control to reduce variability. This is thought to be due to an increase in control arising from better and faster use of perceptual feedback and greater use of feed forward mechanisms (Deutsch & Newell, 2005 in Adolph et al. 2014) and less noise in the sensory motor system (Schmidt & Lee, 2011 in Adolph et al., 2014). Thus researchers consider decrease in intra individual variability to be a sign of skilled performance and control and decrease in variability accompanies more consistent, accurate and economical performance.

Successful performance of most everyday activities in the real world requires some variability (Adolph et al., 2014). This is because local conditions are in a state of flux and motor behaviour has to adapt to these variations in the body, the environment and task. Simply repeating the same movements in the same way would not result in successful execution of the task. Variable movements and a variety of strategies allow the tailoring of motor actions to current situations and allow behaviour to be flexibly adapted to current constraints because, outside the laboratory, local conditions are never constant (Adolph et al., 2014). With sufficient experience in a variety of everyday situations children can adapt movements simultaneously to variable changes in their body and environment. New strategies arise in the course of coping with the task and the more ways to tackle a problem increases the probability of selecting a satisfactory solution. Adolph et al. describe these as 'raw materials to learn' and suggest that regardless of intent, continuance or increase in intra individual variability serve as an exploratory function (Adolph et al., 2014; Hadders Algra, 2000). Furthermore, Adolph et al. (2014) suggest that opportunities for learning variable movements in action create a variety of strategies that, in turn, generate information about the environment, the self and, importantly, the relations between them. They also suggest that this increase in intra individual variation is imperative from the perspective of learning and development because a selection process requires many variants to act upon.

From this perspective intra individual variability is viewed as an important aspect of development.

Davids et al. (2003) propose that dynamical systems framework has influenced the way in which we can view inter- and intra-individual variability in motor performance, as a function of learning and development across the lifespan. They explain that skilled performers can freeze and unfreeze the degree of freedom (DOF) in response to constraint demand within the chain of movement. Whereas, less skilled performers tend to rigidly fix DOF and show variability that is not functional due to their inferior adaptability to task constraints. Furthermore, they urge us to consider functional variability of motor behaviour as a key criterion of successful performance and that motor patterns emerge

under different task constraints to achieve stable task outcomes, rather than pre-determined invariant (Davids et al., 2003, p249). See Fig. 3.1 for a diagrammatic representation. Perhaps the difficulty in adapting to different tasks and situations often displayed by children with DCD could be due to their difficulty unfreezing the degrees of freedom.

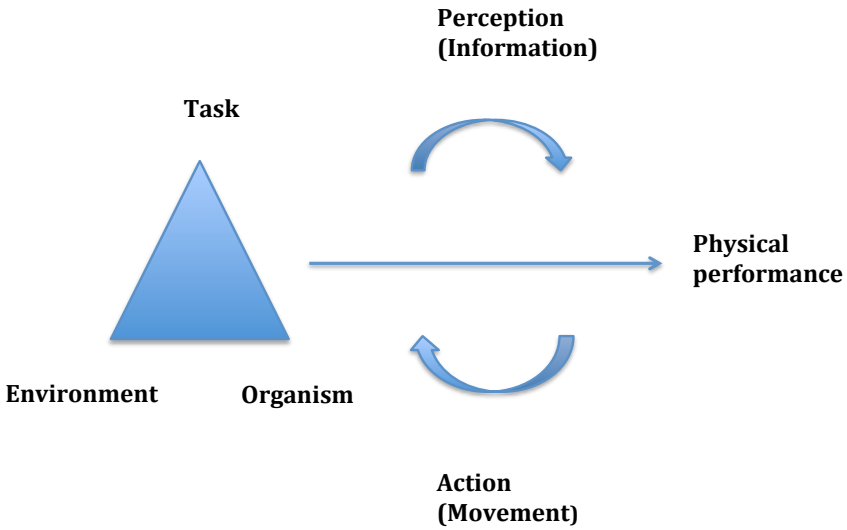


Figure 3-1 Newell's model of interacting constraints adapted to illustrate the resulting effects on variability of physical performance (David's et al., 2003)

3.6.2 The role of variability in typical and atypical motor development

Recent work suggests that suboptimal levels of intra individual variability, that is too much or too little, can distinguish children with typical development from those with disabilities and delays (Adolph et al, 2014). For example, children with Down syndrome frequently show increased amounts of intra individual variability in basic motor skills relative to typically developing children (Looper et al., 2006 in Adolph et al. 2014). Conversely, children with cerebral palsy have

less variable and more stereotyped movement and a limited capacity to vary motor behaviour, i.e. limited variability (Hadders-Algra, 2010).

Successful adaptive movements require different body parts to work together with coordination of joints and limbs and different aspects of the movement to be controlled simultaneously. Thus a challenge for skill acquisition is learning to coordinate the body as a single unit, rather than a collection of separate parts (Adolph et al. 2014) and so any child who encounters difficulty coordinating their limbs with movement of their body will have difficulty learning skilled movement. Observation of change in variability of motor performance should reveal information on the progress of motor skill acquisition and highlight any difficulties.

However, Smith and Wade (2015) urge us to consider how variability is analysed, as it can be viewed as ‘good’ or ‘bad’ depending upon the technique used and the theoretical stance taken. For example, variability interpreted as the ability to make ongoing adjustments in response to changing environmental and task constraints, as observed in skilled performers, is seen as flexibility and therefore ‘good’; whereas variability analysed with standard linear techniques interprets variability as ‘noise’ or output errors, does not reveal the ongoing dynamics and is interpreted as ‘bad’ (Smith & wade, 2015, p50).

Adolph et al. (2014) suggest that a major shortcoming in research is our lack of knowledge about how different types of intra individual variability promote and hinder healthy development. Most research findings are consistent with the idea that some amount of some types of intra individual variability is conducive to healthy learning and development of basic motor skills. However, they state that there is a paucity of experimental evidence to support this notion, but that identifying differences in the amount/structure of variability between children with typical development and those with disabilities is a “promising first step’.

Therefore, future research in the field of DCD should identify the amount of variability in motor development between TDC and children with DCD, to see if this could be a useful tool to distinguish those with particular difficulties.

Of course, variability in the development of motor control can be influenced by many factors, whether within the child, the task or the environmental context. The bidirectional relationship of the developing child and the environment has already been discussed in relation to child development, but there is also thought to be a bidirectional relationship between the development of motor control and the development of perception and cognition (Adolph, 2018). The consideration of how cognitive development influences motor development and vice versa and how this is explained is addressed by an approach called embodied cognition.

3.7 Embodied cognition

In direct contrast to the information processing theory and other classical cognitive theories, embodied cognition emphasizes the importance of the body for cognitive processing, rather than focusing solely on the brain. It is posited, in embodied cognition, that through the body interacting with the environment the sensorimotor experiences help with the acquisition and representation of conceptual knowledge (Wellsby & Paxmen, 2014). Thus motor development has come to be viewed as a process that goes hand in hand with cognitive development, rather than as a function of independent biological processes (Sugden & Wade, 2013). Embodied cognition, includes dynamical systems theory and social behaviour theory, and purports that cognition emerges from the interaction of sensori-motor actions of the baby with his or her environment (Sugden & Soucie, 2017). Leonard (2016) further suggests that motor development provides opportunities for the development of a range of perceptual, social and cognitive skills and is also influenced by these abilities. From this perspective, children with any motor or perceptual motor difficulties are going to be disadvantaged, not only in their cognitive development, but also in social and other domains. Thus children with DCD, because of their poor motor control, are likely to face a double developmental disadvantage.

An area of cognitive function that has been the focus of attention of research in DCD has been that of executive function. Executive functions involve planning, organization, decisions and response inhibition and they have a direct impact on behaviour and performance.

3.7.1 Executive function

Executive function (EF) difficulties have been widely reported to be problematic for children with DCD (Wilson et al., 2013), yet some of the research has been questioned. For example, Leonard & Hill (2015) have critiqued methodological issues with some of the research and caution that future research investigating EF should delve deeper into the underlying causes of performance differences by carefully considering methodological factors such as the domains and samples tested, the informational constraints of the task, as well as the neural underpinnings of the behaviour observed.

Nevertheless, a child's confidence, attention and memory (executive functions) all affect their motor performance (Sugden, 2018), and can influence their participation either positively or negatively. Clinically we find that children with DCD often lack the confidence to engage in physical games with their peers and so will miss out on the social and perceptual skills associated with that play. As all appear to agree that there is a close association between motor skills and perceptual, cognitive and social abilities over the course of development, this lack of physical engagement could have serious implications for children with DCD, if it is not addressed. Indeed, if we now return to Adolph (2018), her five principles of motor development provide us with another way of viewing motor development and provide scope for potential opportunities to intervene at many levels to influence it's course.

3.8 Adolph's five principles of motor development

Adolph (2018) suggests that the study of motor development has a broad scope, because it refers to improvements and decrements in motor skill over the life span. She proposes five core principles. The first principle concerns the nature of motor development, not characterized as a series of stages, but by it's inherent equifinality (multiple pathways to the same endpoint) and multifinality (multiple outcomes from the same starting point). She gives the examples of these with the manifestation of mature skills in young adults often taking different forms and the different ways that elderly adults compensate for decrements in skill. She also points to individual differences and intra-individual variability as evidence of this.

The second principle concerns body-environment reciprocity, whereby motor actions depend upon the physical constraints of both body and environment. Here the development of motor actions reflects changes in the fit between variations in the environment and changes in body characteristics, for example strength, endurance, leg length etc. relative to step height and number of steps, as changes in either alter possibilities for stair climbing action.

The next principle is perception-action coupling; Adolph argues that motor development involves changes in psychological functions in addition to changes in biomechanics, because the continually varying physical constraints requires perception (and sometimes cognition) in order to adaptively guide the motor actions. She argues that movements are controlled optimally prospectively (e.g. whether a narrow gap is passable) and require perceptual information about possibilities for action and that exploratory activity and feedback from the active movements generate the requisite perceptual information.

The fourth principle is experience; Adolph argues that motor development is only age related, not age determined, because experience affects the ages that skills first appear, the form they take and which skills are acquired. For

example, the onset of walking from 9-18 months, sitting with legs out or in deep squat, and whether an individual crawls, rides a bike, swims or drives a car is all experience dependent. She further contends that active self-generated experience is more powerful than those received passively. Cultural expectations and child rearing customs play a large role in determining the variety of experiences and skills.

Finally, she proposes the principle of developmental cascades, whereby changes in one motor skill bring about changes in other motor skills and lead to changes in other domains. For example, independent locomotion brings about changes in spatial cognition and memory and walking ability stimulates changes in adult-child social interactions leading to changes in emotional independence.

So we see that successful motor development has the potential for wide ranging positive impact on the rest of a child's development. However, this also serves to emphasize the disadvantage that children with DCD can face through poor motor control, but equally challenges us to consider the different levels at which some of the constraints could be ameliorated. One of which could be the provision of active positive movement experience. This leads us to consider some of the constraints in active movement experience for children with DCD, in particular, participation in physical activity. The first of these is the perception a child has about his or her movement competence.

3.9 The influence of self perceptions of motor competence in physical activity

It is widely accepted that participation in physical activity influences children's motor skill development and a widely held belief that the more proficient their skills become the more likely they are to engage in physical activity. Stodden et al. (2008) conceived of a model to test whether perceived movement competence was a mediator to influence levels of physical activity in children.

Slykerman et al. (2016) conducted a cross sectional study of 109 young children (mean age 6.5) that included a test of actual motor ability, a test of their perceived movement skill and accelerometers to measure intensity of PA and found that actual, rather than perceived motor skill competence, was more important for engagement in moderate to vigorous PA (MPVA). These results contrasted previous results with older children, whereby perceptions of physical competence were found to predict MPVA (Babic et al., 2014). Although Slykerman et al. (2016) suggest that for children less than 8 years old perceptions of their competence tend to be inflated as movement competence is still developing. However, Slykerman and colleagues concluded that the relationship between skill type and PA behaviour was not clear, although it was influenced by age, sex and instrumentation differences.

It is important to note that the model proposed by Stodden et al., (2008) acknowledged the developmental changes in children's self-perceived competence. They suggested that young children lack the cognitive ability to distinguish accurately between effort and actual motor skill competence and over inflate their ability, because they equate expenditure of effort with skill. Whereas, by middle childhood, when cognition has developed further, they are able to compare themselves with their peers so that their actual motor competence relates more closely to their perceived motor competence. That is, those children with lower motor competence will have lower perceived motor competence and therefore, Stodden et al. (2008) predict a lower engagement in PA. They argue that this leads to vulnerability of children with low motor competence to withdraw from PA and run health risks of being sedentary, for fear of publicly displaying their low motor competence. However, Babic et al. (2014) suggest that the relationship between self-perception of motor competence and engagement in PA is less strong in late adolescence. One suggestion is that team sports become less important and teens engage more in resistance training, walking, aerobics and other non-traditional activities, possibly less likely to be captured on traditional scales and so effecting the results (Babic et al., 2014).

Children with DCD participate less in physical activity (Rivalis et al., 2011) and also have been reported to have lower self-perception of athletic competence and social acceptance (Skinner & Piek, 2001). A positive self-perception of motor skill competence is going to be important for engagement of children in PA, but the exact nature and relationship requires more study. Other factors may be equally important.

Barnett et al. (2016) conducted a systematic review to identify potential correlates of gross motor competence in TDC aged 3-18 years using an ecological approach. Barnett et al. (2016) suggested that ecological models could be used to frame potential influencing factors, as they emphasize environmental contexts of the behaviour as well as the psychological and social influences. This way multiple spheres of influence can be understood in-depth and can help guide the development of intervention. They found that, of the 59 studies published between 1995 and 2014, the most examined correlates were biological and demographic. Findings included that a healthy weight status, being male and coming from a higher socioeconomic background were all consistent correlates, but only for certain aspects of motor competence, depending upon how it was operationalized. Only increasing age was consistently a correlate of all aspects of children's motor competence. PA was a positive correlate of motor coordination, but there was indeterminate evidence for PA being a correlate of object control or locomotor skill competence. Moreover, few studies investigated cognitive, emotional and psychological factors, cultural and social factors or physical or environmental factors (Barnett et al., 2016). This suggests that more research is required, using an ecological framework, as there are gaps in current understanding of perceived motor competence and potential correlates of motor skill competence.

3.10 Parental support and attitude to participation in PA

An area of study thought to influence children's participation in PA is parental attitude to PA and parental behaviour towards PA. However, before exploring this, it will be helpful to define and explain participation. Participation is often described as a key rehabilitation outcome and has been shown to be an

indicator of overall health and well being across the lifespan (Bedell et al., 2013). The ICF defines participation as 'involvement in a life situation' and participation restriction as 'problems and individual may experience in involvement in life situations' (WHO, 2001). Imms et al. (2016) conducted a systematic review of the language, definition and constructs used in research on participation of children with disabilities, as there was no universally accepted definition of participation. They found emergence of five themes from their analysis of studies on participation: preferences, attendance and involvement (related to 'being there' and subjective 'in the moment experiences'), activity competence and sense of self. They suggest that the themes are linked, because preference for a particular activity is likely to lead to attendance to engage in it and then involvement becomes possible. Attendance and involvement may lead to competence in the activity and improve self-confidence, which in turn may influence preferences (Imms et al., 2016).

This may well be the case for children with DCD, as they are thought to have reduced participation in physical activity. Cairney et al. (2005) found that boys with DCD had significantly lower participation rates in recreational PA than typically developing boys, a finding also supported by Batey et al. (2014). Moreover, Poulsen et al. (2007) found that children with DCD were unsuccessful in engaging in team sports and reported loneliness. Clearly, children with DCD are at risk of missing out on the social and physical benefits of engaging in PA and, from an embodied cognition perspective, missing potentially improving their experience and competence in motor and a number of other domains.

Welk (1999) studied the determinants of physical activity in children and concluded that they were multifactorial. He suggested that the family plays an important role in shaping children's activity habits through reinforcing factors, such as taking children to parks and exercising with them as well as parental encouragement. He also proposed a model for a conceptual framework for

understanding factors that may predispose, enable and reinforce a child to be physically active. It included multiple levels of influence (intrapersonal, sociocultural and environmental) and supports the idea of reciprocal interaction between the child, the environment and the behaviour (Welk, 1999). King et al. (2003) agree that participation is a complex concept and is influenced by personal factors related to the child and family and to environmental factors and even more complex for children with motor difficulties. Anaby et al. (2014) found that some of the most common facilitators of participation for children with disabilities involved social support of the family and friends and geographic locations and the most common barriers included attitudes, physical environment, transportation, policies and lack of support from service providers. Therefore, any research examining participation in PA should include an ecological approach to understand some of the family and environmental factors influencing the child.

3.11 Chapter Summary

Current understanding of motor development has shifted from considering the child in isolation to include a more transactional approach to the development of the child within his or her environment. Dynamical systems theory facilitates consideration of the nature of the role of the environment (physical, social and cultural) in providing affordances or barriers for children's self generated motor experiences, for the optimal development of motor and other skills, from our current understanding of embodied cognition. Traditional views about the nature of change in motor ability have also been discussed in relation to variability in motor performance and it's potential to distinguish typical from atypical motor development. It has also been noted that motor skill acquisition in children not only relies on practice, but is also influenced by experience, perceptual, cognitive and social factors and others such as perceived competence and parental and cultural influence. However, without exploring the progression of motor abilities from an ecological perspective, some of these important influences could be overlooked. Bronfenbrenner's bio ecological model is a useful framework with which to examine some of these factors. DCD is a disorder of motor development, yet we still do not fully understand how and

why the motor development of children with DCD progresses differently over time. The next chapter will explore some of the issues in DCD research that seeks to answer some of these issues.

CHAPTER 4 CURRENT ISSUES IN DEVELOPMENTAL COORDINATION DISORDER

Understanding the course and prognosis of a disorder helps with the planning of services for appropriate intervention. However, this is not straightforward in DCD, as tensions exist associated with the identification and assessment of children with DCD and the way these influence how DCD is studied over time. Longitudinal study is a way to chart developmental progress and a number of such studies have been undertaken in the last three decades for DCD. This chapter will begin with a discussion of the prevalence of DCD and current knowledge of the course and prognosis of the disorder. Some longitudinal studies in DCD will be discussed and a number of methodological issues will be considered with the implications that they have on the study findings.

4.1 Prevalence of DCD

The prevalence of DCD is often reported as 5-6% of the population (DSM-5, APA, 2013). However, since there are no biomarkers for DCD and the diagnosis relies on interpretation of behavioural criteria, a few issues have arisen. For example, different studies have reported widely different prevalence rates ranging from 1.8 to 19.0% (Lingam et al., 2009; Tsiotra et al., 2006; Wright & Sugden, 1996), exposing discrepancy in adherence to the diagnostic criteria and measurement issues concerning the use of specific assessment tools (Zwicker et al., 2012; Barnett, 2008). Wright & Sugden (1996) questioned the prevalence rate in DCD, as it was rarely based on epidemiological studies and was subject to definitional difficulties. They chose a random population in Singapore and found the rate of DCD at 16% of children, 12% “at risk” with moderate impairment and 4% seriously impaired. Later, an epidemiological study by Lingam et al., (2009) used DSM-IV criteria and found a prevalence rate, in a UK birth cohort, of 1.8% severe DCD and 4% moderate impairment at age 7 years. However, not all DCD research can be based on epidemiological studies due to the expense involved. Clearly, prevalence rate will be dependent on both strict adherence to the diagnostic criteria adopted for DCD and the cut-

off levels of the motor assessment used and so any future research needs to make these explicit. To add a further problem, not all motor assessments measure the same things, as different tests will identify different children and no motor test covers the full range of motor skills (Albaret & de Castelnau, 2007).

A further complication is that there is still no agreement among experts about the threshold for motor cut-off for DCD diagnosis, as EACD recommend 15th percentile whilst the Leeds consensus recommends 5th percentile. Furthermore, different published studies used different motor cut-off thresholds, for example 5th, 10th or 15th percentile and then did not necessarily analyse the results separately, making comparison across studies difficult. However, Larkin & Cermak (2002) described cut scores (cut-off thresholds) as an arbitrarily designated point of motor impairment and suggested that few tests can reliably distinguish between examinees with adjacent scores, further warning that motor test scores devoid of context are a naïve way to identify motor problems. Therefore, in order to appropriately identify children with DCD, an appropriate motor assessment (with explicit cut points) in addition to children's contextual information is necessary.

4.2 Gender ratio

Another consideration is the disproportionate ratio of males to females (3:1) (APA, 2000) often quoted in DCD research. Nevertheless, this has been recently questioned by employing population- based sampling and finding more equal sex ratios (Missiuna et al, 2011). A wider question is whether there is actually a lower prevalence of DCD in girls or, whether it is an under representation of girls in the published research or just reflects a higher rate of referral of boys to health and educational support services for movement problems. Either way, this warrants further investigation to establish if the 'gatekeepers', such as parents and teachers are inadvertently under referring girls for DCD assessment, as cultural expectations of girls motor performance is lower.

4.3 Measurement issues and fulfiling diagnostic criteria for DCD

The importance of internationally agreed criteria for the identification and diagnosis of DCD has already been discussed, however, the type of screening and assessment tools employed will also have a significant bearing on the identification and classification of children with suspected motor difficulties for the DSM criteria.

4.3.1 Measurement tools for criterion A:

Many tools identify motor problems in children suspected of having DCD and help to fulfil criterion A in the DSM diagnostic criteria. However, one criticism is that the motor tests employed for the diagnosis of DCD have tended to emphasize motor proficiency rather than the development of coordination (Larkin and Rose, 2005). Examples of these include the Movement Assessment Battery for Children (MABC) (Henderson & Sugden, 1992), the McCarron Assessment of Neuromuscular Development (MAND) (McCarron, 1982) and the Bruininks Oseretski Test of Motor Proficiency (BOTMP) (Bruininks, 1978). However, the high correlation between the total test scores of the MABC the MAND and the BOTMP and the validity studies of all three tests provides evidence for a general construct of motor ability or motor coordination (Larkin and Rose, 2005) and therefore validates their use in the identification of DCD. The BOTMP2 and the MABC2 are revised versions of their precursor tests and include extended age ranges to cover adolescence, which is an important addition for longitudinal research. It is often said that there is no ‘gold standard’ motor test, however the EACD guidelines endorsed the use of the MABC2 in the assessment of DCD (Blank et al., 2012) because it has good validity and is widely used.

Kaplan et al (1998) raised some important issues about identification and classification of the developmental disorders. They used three different assessments to classify DCD, namely two motor assessments the Bruininks-Oseretski Test of Motor Proficiency (BOTMP) (Bruininks, 1978) and the

Movement Assessment Battery for Children (MABC) (Henderson & Sugden, 1992) and a parent questionnaire the Developmental Coordination Disorder Questionnaire (DCDQ) (Wilson, Dewey & Kaplan, 1998). This study not only highlighted interesting points about choice of cut-off scores, but also recognized that different tests identified different children with DCD. The 15th percentile was chosen as a cut-off for MABC and <42 standard score for BOTMP and less than 1 SD below the group mean for the DCDQ. However, this led to a DCD prevalence rate of 21.4%, which included both the index group and the typically developing controls, and is much higher than previously reported by other studies, which stated rates from 2.7% to 15.6% (Wright, 1997). Furthermore, even 13% of the control group was classified as DCD, which seems disproportionately high and perhaps suggests too lenient inclusion criteria.

It also highlights the concepts of sensitivity (how accurate) and specificity (ability to determine DCD children from non DCD) in testing, which can lead to over diagnosis or 'false positives', identified by a test, and may well have been the case here. Moreover, Kaplan et al. (1998) recruited subjects between 1992 and 1997, which indicates that the start date of the study preceded any consensus on diagnostic criteria for DCD. It is unclear if this sample represented what we now understand as DCD or a more heterogeneous group. There are myriad reasons for motor impairment, including those resulting from a medical condition or neurological damage. Medical reasons can explain underlying aetiology and therefore the children can differ considerably from children with motor impairment without a known reason. This highlights again the importance in research about clear agreement on diagnostic criteria and is the reason that the research community has now adopted DSM-5.

Albaret & De Castelnau (2007) recommend that motor cut points should not be the only basis for decision for diagnosis, as the nature and effects on everyday life may be more pertinent. One way of obtaining this information is by way of a criterion-referenced checklist.

4.3.2 Checklists to assess impact of motor impairment on function for criterion B

Information gleaned from someone that knows the child well and can observe how motor impairs function on a daily basis will fulfil criterion B. A checklist provides a relatively quick and inexpensive way of collecting this information.

Wright & Sugden (1996) described a two-step procedure that provided a cost effective way of screening children with movement difficulties, so that only those at risk would need to undergo full norm referenced motor assessment. The MABC checklist was completed by parents and teachers to indicate where there were functional problems and any child, whose score indicted problems severe enough to suspect DCD, was then assessed with the MABC. Screening like this permits the easy assessment of large numbers of children and has been adopted by large-scale population studies, such as the Canadian study by Missiuna et al. (2011).

Several checklists are available for use with children suspected of DCD. These include the Developmental Coordination Questionnaire (DCDQ) (Wilson, Kaplan, Crawford, Campbell & Dewey, 2000), the DCDQ (07) (Wilson & Campbell, 2007), the MABC checklist (Henderson & Sugden, 1992), the Early Years Movement Skills Checklist (Chambers & Sugden, 2002), the Children Activity Scales for Parents and the Children Activity Scales for Teachers (Rosenblum, 2006) and the MABC2 checklist (Henderson, Sugden & Barnett, 2007). Screening tests must have sound psychometric properties, with appropriate levels of sensitivity (how many children are correctly identified with impairment) and specificity (how many children are correctly identified as free from impairment). Unfortunately, these tests had variable results relating to their sensitivity, with correct identification of children with DCD ranging from 50-100% (See Barnett, 2008 for a discussion). A usual minimum expected level of sensitivity is 80% (APA, 2000). Despite this, checklists offer valuable observations of the child's performance in their everyday context and identify areas for intervention to help improve the child's daily function.

4.3.3 Onset of symptoms in early developmental period Criterion C

Delayed motor milestones (such as sitting, crawling and walking) are often early symptoms of DCD (APA, 1995, p56). Parents frequently report that their pre-school children with DCD had great difficulty acquiring self-care skills, such as using cutlery, dressing and grooming and that any play requiring balance and coordination was problematic. This information can be obtained by parent interview or questionnaire and is an important part of the diagnostic process.

However, many of these symptoms are also present in children that are born prematurely or with very low birth weight, which has led to a debate about whether these children should receive a diagnosis of DCD or not. Both subtle learning problems and motor clumsiness have been noted in children born prematurely or with low birth weight (Foulder-Hughes & Cooke, 2003). Furthermore, an association between the motor competences at six years old and the duration of flares in the periventricular white matter of preterm babies has been found (Jongmans et al, 1998), inferring subtle damage to the brain. Moreover, an increased prevalence of DCD at aged 8 has been reported in extremely low birth weight and extremely premature babies (Roberts et al, 2011). This has led to debate about the appropriate application of the DCD diagnostic criteria and inclusion/exclusion criteria in the DSM IV (see Barnett, 2011 for a discussion). Given the known increased risk of cerebral palsy (CP) in this group of children there is also now some question about the notion of a cerebral palsy-DCD continuum (Pearsall-Jones, Piek & Levy, 2010a), suggesting that DCD in this group may be a mild form of CP. A detailed birth history should be included in any assessment and noted in any samples for research, in order to determine if these children constitute a different group in relation to symptoms and intervention.

Williams et al. (2014) reviewed existing research on risk factors and neurophysiological evidence to support understanding of underlying neural mechanisms for CP and DCD. They concluded that, although there are

common peri- and neonatal factors for CP and DCD, the neurophysiological data are conflicting. There is, however, evidence of overlap in micro- and macro-structural abnormalities of the two disorders, but only when DCD samples include children exposed to pre- and peri-natal adversities. They established that no firm conclusions can be drawn on the CP-DCD continuum at present, but the most likely candidates for a CP–DCD continuum would be a subgroup of DCD born preterm, given their significant overlap in risk factors. However, more research comparing samples of children with DCD with and without pre- and perinatal adversity is required.

4.3.4 Motor impairment not better explained by known neurological disorder, visual or intellectual impairment for criterion D

The presence of intellectual impairment in DCD causes some tension with this criterion. For example, the Leeds consensus recommended that if a child had an IQ, presumed or measured, below 70 they should not be given the diagnosis of DCD (Sugden et al. 2006, p7). The argument presented was that within the typical range of IQ the relationship between motor competence and IQ is low, but as soon the IQ drops below 70 the relationship begins to rise (Sugden & Wade, 2013). Therefore, children with moderate learning difficulties (IQ 50-70) are more likely to have motor difficulties than TDC.

However, DSM IV TR (APA, 2000) does not stipulate an IQ threshold, merely stating that if mental retardation is present the motor difficulties should be 'in excess of those associated with it'. DSM5 (APA, 2013) is even less specific, stating that the motor skills deficits should 'not be better explained by intellectual retardation'. Furthermore, the EACD guidelines concluded that a specific IQ level does not seem helpful to distinguish between children with DCD and those with coordination problems due to mental retardation (Blank et al., 2012, p63). The situation thus appears to be open to the professional interpretation of a clinician or researcher. The only caveat is that an idea of intellectual ability should be obtained for any child with a potential diagnosis of DCD, in order to gauge whether the motor deficits are in excess of those expected for the IQ level. Ideally, a measure of IQ should be made; where not

feasible a teacher's opinion or national tests results may be acceptable (Sugden & Wade, 2013, p232).

The second issue concerns ruling out other diagnoses such as visual impairment or neurological conditions. Zwicker & Mickelson (2017) undertook a prospective cohort study to determine which other conditions could present like DCD using DSM5 criteria. They adopted a two–step procedure using the DCDQ checklist (Wilson et al., 2007) completed by a caregiver, a standardized motor test completed by an OT, a neurological examination and developmental history completed by a paediatrician. Over 100 children suspected of DCD were assessed and 71% met the criteria for DCD and 29% met the diagnostic criteria for another disorder. Of the 29% who met the criteria for other conditions, 50% were diagnosed with a neurodevelopmental disorder (e.g. ADHD, foetal alcohol syndrome, ASD or learning disability), 25% were diagnosed with a neurological condition (e.g. CP, hypotonia, seizure disorder, Chiari I malformation) and the remaining 25% were diagnosed with a genetic or medical condition (e.g. Ehlers-Danlos syndrome, Neurofibromatosis Type I, microdeletion syndromes).

This study highlights the importance of professional awareness of differential diagnoses for DCD with known neurological disorders, other neurodevelopmental disorders and medical conditions and for them to recognize the red flag symptoms so that the child can be referred on to a specialist for the appropriate assessment and intervention. Zwicker & Mickelson (2017) suggest that a paediatrician should assess all children suspected of having DCD and, whilst this is essential in a clinical setting, it is not always possible in a research setting.

A recent review by Smits-Engelsman et al. (2015) investigated how well authors, who had published between 2010 and 2015, had complied with DSM criteria in the description of the children they selected with DCD. They summarized 176 papers and found that most papers provided detailed

information on motor performance using standardized scores with reported cut-off values, but few provided sufficient detail about how IQ or other diagnoses had been ruled out and only 12% of papers had reported that a paediatrician had assessed children. This can be problematic in a number of ways as it makes it difficult to compare studies. We cannot be sure that all those labelled DCD actually meet the DSM criteria and it also does not rule out confounding variables, such as level of IQ and presence of other conditions. This is particularly important in longitudinal research investigating the course and outcome of DCD, as it is difficult to attribute the outcomes to DCD without first ruling out these confounding variables.

Summary

Diagnosis for DCD is not straightforward, despite internationally agreed diagnostic criteria. Although research in the field of DCD has greatly increased awareness of the disorder, future research should make explicit how the diagnostic criteria have been met in order to permit more detailed comparison across studies. Identification and diagnosis are an important first step, but given the complexity and heterogeneity of the disorder, understanding the course and prognosis of DCD are equally important in order to facilitate the development of appropriate interventions. Longitudinal studies are an important way to establish the nature of a disorder and how it may progress over time. A number of longitudinal studies have contributed to our current understanding of DCD, but they are not without methodological issues, which need to be clarified.

4.4 Longitudinal evidence: course and outcome of DCD

Longitudinal studies allow the opportunity to assess the same children over a number of occasions to monitor the changes that occur and relate the changes in one skill to changes in another (Hulme and Snowling, 2009). This facilitates the description of patterns of change and allows researchers to establish the direction (positive or negative) and magnitude of causal relationships (Menard, 2002). Moreover, it would be impossible to disentangle developmental (age),

historical (period) and cohort effects on change without longitudinal data (Menard, 2002) and only longitudinal data reflects intra-individual change.

However, analysis of the course and outcome of DCD is not straightforward due to many methodological constraints in the published longitudinal studies. For example, different studies used different diagnostic criteria to identify DCD, and pre- 1994 there were no consensus agreement about which criteria to use. Earlier studies from the 1980s, then followed up in the 1990s have informed our understanding of DCD, and although some had DSM criteria retrospectively applied, there is still an element of uncertainty about how all the criteria were met. Even after the 1994 consensus agreement, not all studies identified how they had met DSM criteria (Geuze et al., 2001). Smits-Engelsman et al. (2015) also noted that the situation had not changed much over a decade later, even following the 2006 Leeds consensus, as few published studies stated how DCD diagnostic criteria were met. The situation is compounded by use of different measurement and screening tools, which make direct comparison between studies more problematic, as different tools measure different items and can potentially identify different children (Albaret & de Castelnau, 2007).

Longitudinal studies concerning DCD also have different lengths of follow up time, ranging from 1.5 (Pless et al., 2002) to over 15 years (Rasmussen & Gillberg, 2000). This also makes comparison difficult, because of the different developmental stages of the children studied. For example, Knuckey & Gubbay (1983) found that children with mild to moderate motor difficulty aged 8-12 years had improved by age 16-20 years, and proffered developmental lag as a potential cause for DCD. However, there is some debate about the role of adolescence in motor progression in DCD (Cantell & Kooistra, 2002; Visser et al., 1998) and whether children actually improved during this period or whether it was a ceiling effect of the different motor measures that were only standardized up to age 12 years. Moreover, difference in the theoretical approach taken by the different studies inevitably affects the method and type of data collected and how it is interpreted.

Cantell & Kooistra (2002) summarized the longitudinal studies pre 2000 and suggested that they fell broadly under two different categories. The first was the optimistic approach, which considered DCD largely a disorder of childhood and on the lower end of a continuum of motor severity. The suggestion was that DCD was possibly due to a developmental lag, as study findings showed that some children had improved by late adolescence (Hall, 1988; Knuckey & Gubbay, 1983). The second was more pessimistic and was based on study findings that showed persistent impairment in the children with more severe symptoms (Ahonen, 1990; Geuze & Borger, 1993; Hellgren et al., 1993, Losse et al., 1991). Furthermore, Cantell et al. (1994) and Cantell (1998) suggested that severity of symptoms related to the persistency of DCD, since they found that children with mild to moderate difficulties improved over time to a typical level, whilst those with severe problems had persistent DCD.

4.4.1 Different motor outcomes for children with DCD

This differential motor outcome for children with DCD deserves closer investigation, since confounding variables such as IQ, the presence of other conditions and even the different experiences due to socio-economic context can influence outcome. However, the possible significance of children with milder symptoms, often referred to as a moderate DCD/at risk DCD group, could be important and further examination of findings from longitudinal studies can help uncover more detail.

In order to understand the nature and impact of a developmental disorder it is necessary to relate it to typical development (Hulme & Snowling, 2009), otherwise any changes noted may be attributed to the disorder rather than the change as the child develops. A number of longitudinal studies comparing children with DCD to typically developing children (TDC) have been reported (Geuze & Borger, 1993; Losse et al., 1991; Cantell, Smyth & Ahonen, 2003; Rasmussen & Gillberg, 2000; Lingam, Golding, Jongmans, Hunt, Ellis & Emond, 2009; Cairney, Hay, Veldhuizen, Missiuna & Faught, 2009). There is clear empirical evidence that DCD persists into adolescence and adulthood and is not a benign disorder.

However, findings of particular note from the earlier studies indicate that children with DCD, significantly differ from typically developing children (TDC) five or even 10 years later, but nevertheless show a wide variation from each other. For example, Geuze & Borger (1993) tested children aged 6-12 years matched for age, sex and school and found that 50% of the children identified with DCD still displayed motor impairment 5 years later (aged 11-17 years) and scored below 15th percentile on a test for motor ability, whereas the other 50% scored above the 15th percentile, with some even achieving a score in the typical range. This wide variation, despite a small sample size (DCD n=12; TDC n=14), warrants explanation as it could indicate different trajectories for children with DCD. However, several questions remain about the sensitivity of the test used, as it was only standardized for children up to age 12 years, and may not have been able to detect differences in the older age groups. The DCD group also reported less social contact and less participation in sport, perhaps indicating ongoing difficulties, despite achieving motor competence in the test. Unfortunately, the children were not matched for IQ or socio-economic status (SES), both of which could have an impact on social and sport participation.

Yet, other studies report similar findings, Cantell, Smyth and Ahonen (2003) found significant group difference between DCD and TDC children, but that the DCD children appeared to follow different trajectories from each other in their study, which followed children from 5 to 17 years of age. The difference in this study was that a distinction was made between the severities of perceptual motor difficulty (significant or minor) of the children with DCD. Those with severe perceptual motor problems appeared to continue to have difficulties, whereas those with only minor perceptual motor problems (the intermediate group) appeared to perform at a level close to the control group by age 17. Cantell et al (2003) suggested two possible explanations for the apparent catch up; either the tasks used to distinguish the groups lost adequate power with increasing age, or the intermediate adolescent group really caught up to their typically developing peers. They reviewed other follow-up studies and concluded that all the DCD children studied reported developmental change,

but not in a homogeneous pattern. Some studies reported improvement or “repair” by the onset of puberty (Sooranami-Lunsing et al., 1994; Visser et al., 1998), with suggestions of the benefits of physical growth, adaptation of the central nervous system and increasing movement experience with age, as possible explanations for the improvement in motor performance (Cantell et al., 2003). In addition, they questioned the confounding role of IQ in outcome and noted that the children in their study with lower IQ had a poorer school outcome.

However, there may be a more complex interaction at play here, as the results from another longitudinal study by Losse et al. (1991) found that even the DCD children with high IQ aged six had poorer academic outcomes than controls 10 years later. Another finding, indicating that multiple factors are involved in the functional outcomes for children with DCD, was that variations in the self-concept and motor ability of the DCD group; their self-concept bore no pattern to their motor ability or PE attainment (Losse et al., 1991). Another important finding was that the children reported intense feelings of personal failure and many had additional problems with handwriting, concentration and behaviour and reported less enjoyment in sport, leisure and school. It may be that associated problems in non-motor areas have a larger impact on the developmental trajectory and functional outcome for children with DCD, or possibly different subtypes of DCD, which could account for such heterogeneity.

Summary

There is strong empirical support that children with DCD differ from TDC in their motor performance over time, but equally there is considerable intra group variability between children with DCD. Even within groups of DCD children with severe motor impairment heterogeneity has been reported (Kirby, 2005). It is therefore not clear which factors have the greatest influence on motor progression for children with DCD, but co-occurrence of other disorders, existence of subtypes of DCD, varying levels of IQ, self perception of their motor abilities, family context and even the presence of secondary problems have all been the focus of previous investigation, but methodological issues

have clouded the picture. Questions such as these will remain unanswerable unless there is strict adherence to the diagnostic criteria for DCD. Moreover, valid and reliable tools need to be used for measurement with clear cut-off levels indicating severity of motor difficulty, so that it can be taken into account and identify separate groups of children. Furthermore, confounding variables such as IQ and SES should also be reported.

4.4.2 Heterogeneity in DCD, variable outcomes and possible lines of inquiry

A potential problem in DCD research is that investigations have relied on comparison designs that measure levels of performance on a number of variables between the DCD and TDC. Fisk & Rourke (1979) point out that this strategy assumes implicitly that the children under investigation (in this case the DCD group) constitute a homogeneous population. Clearly, this is not what empirical evidence shows. They therefore suggest investigating subtypes to explore the heterogeneity. Several studies have explored the possibility of subtypes in DCD using an empirical technique known as cluster analysis.

4.4.2.1 The search for subtypes to explain heterogeneity

Wright and Sugden (1996) found large intragroup differences in the children with DCD and used cluster analysis to search for subtypes in DCD. In this approach a set of measurements is obtained and the participants are statistically grouped together on the similarities of their profile of scores (Visser, 2007). Several studies have been conducted using this approach (Hoare, 1994; Wright & Sugden, 1996; Miyahara, 1994; Dewey & Kaplan, 1994; Macnab et al., 2001; Green et al., 2008). However, it has been difficult to compare the results because the participants have been drawn from different countries (Australia, Singapore, USA, Canada and UK), different populations (3 from clinics, 3 from schools) using different diagnostic criteria, different tests of motor ability, different statistical tests, different theoretical positions leading to the choice of different variables to form the clusters (see Macnab et al., 2001 and Visser, 2007 for reviews). Despite this, there is some overlap between the

clusters identified in the studies and all have found a subtype with generalized sensorimotor deficit, but as Visser (2007) explained this is the only group that will show up regardless of the variables used in a study. Macnab et al. (2001) set out to replicate the study by Hoare (1994) and, despite the differences previously mentioned, were able to replicate five clusters fairly well. Green et al. (2008) adopted a similar procedure and also found five clusters, two of which showed a similar pattern to those of Hoare (1994), suggesting that this may be a valuable technique for future studies, providing clear information is stipulated about the population sample and the variables chosen.

However, Visser (2007) argued that subtype studies have contributed little to our understanding of DCD, as it does not explain aetiology and suggested that it would be more fruitful to distinguish subtypes in terms of underlying deficits and examine the developmental trajectories. Furthermore, he suggested that the presence or absence of comorbidities has a direct relevance to the way subtypes of DCD are defined and understanding will only improve if we know why comorbidity is linked to a particular subtype (Visser, 2007, p98).

This is supported by a recent Australian twin study that examined the relationship between movement problems and four developmental disorders by Martin, Piek et al., (2010). They found that the likelihood of comorbidity increased with symptom severity and that the results varied with the presence or absence of reading disorder. Despite the need for caution when extrapolating results from the twin population to the wider population (because of the higher incidence of developmental disorders in twins), future research should at least note the presence of additional developmental disorders in children with DCD.

4.4. 2.2 The influence of Comorbidity/co-occurrence of other disorders with DCD

Comorbidity is described as the simultaneous occurrence or two or more unrelated conditions and epidemiology shows that it is extremely common in

child psychiatry (Caron & Rutter, 1991). Comorbidity is considered when the observed rate of comorbidity exceeds that expected by chance alone; this can be obtained by multiplying the base rates of each of the separate conditions involved (Caron & Rutter, 1991). Common developmental disorders associated with DCD are ADHD, SLI, RD and ASD. According to DSM IV (APA, 2000) the reported prevalence rates of these disorders are DCD 6%, ADHD 3-5%, RD 4% and ASD greater than 1% (Baron Cohen et al., 2009) respectively.

The effect of comorbidity of one developmental disorder with another can have significant implications for learning and progression and, therefore, on the choice of the mode of intervention. Attribution of a problem to a disorder without closer examination and better understanding about the nature and cause of the problem could potentially be attributed to the wrong cause and lead to educational or clinical decisions that may not be appropriate for the individual. Therefore, as comorbidity has been noted in DCD (Kaplan et al., 2006; Martin, Piek et al., 2010), as explained in chapter two, careful consideration of the impact of each disorder should be taken when examining progress and outcome in DCD.

However, Kaplan, Crawford, Cantell, Kooistra and Dewey (2006) questioned use of the term comorbidity associated with DCD and suggested use of the term co-occurrence instead, because the aetiology of DCD is unknown. They argued that the term co-morbidity implies that the nature of underlying cause for each diagnosis are separate from each other, whereas continuum suggests linear severity and probable related causality and co-occurrence implies a purely temporal concept that may or not reflect underlying aetiology (Kaplan et al, 2006). Therefore, the term co-occurrence will be used interchangeably with comorbidity here as it relates to the literature, but no underlying aetiology is inferred.

4.4.2.3 The co-occurrence of ADHD with other disorders

Two of the most common developmental disorders are ADHD and Dyslexia (RD) which occur in approximately 5% of the population, but their rate of co-occurrence has been reported between 18-45% and both molecular genetic and behavioural studies support a partly shared genetic aetiology between ADHD and RD (see a review by Germano, Gagliano and Curatolo, 2010). Moreover, children comorbid for both conditions appear to have more severe cognitive deficits, leading Germano et al. (2010) to suggest that RD could be a marker for a group of children with ADHD with more severe cognitive deficits and worse academic and behavioural outcomes.

Another common comorbidity is ADHD and language impairment (LI). Cohen et al. (2000) examined this in a 2x2 (ADHD, LI) study adhering to strict DSM III criteria and IQ ≥ 85. Their findings demonstrated that the children with ADHD plus LI were associated with worse academic achievement measures and lower performance on working memory tests, leading them to state that this group were at greater risk and call for routine assessment of language competence, as it could have implications for intervention.

Moreover, studies in the area of specific language impairment (SLI) appear to indicate considerable overlap between SLI and RD. For example, McArthur et al. (2000) found that over 50% of 212 children studied met the criteria for both SLI and RD. Furthermore, studies on the developmental trajectory and functional outcome for children with SLI make interesting, if pessimistic reading. Knox (2002) investigated academic achievement and followed 100 school children with SLI and, even after accounting for level of support and special access arrangements, found results similar to Conti-Ramsden (1992), that these children performed much worse than the national average in all subjects, especially English. Therefore, children with SLI are at considerable risk of global academic problems (Tallal et al., 1997).

This highlights the danger of attributing poor outcomes and poor progress in school to DCD alone, without first accounting for the co-occurrence of other disorders, such as ADHD, SLI or ASD in children, as the interaction of different

developmental conditions may have a significant impact on the academic and behavioural outcomes for children.

4.4.2.4 DCD and co-occurrence with other disorders

Co-morbidity is widely reported in DCD. Moreover, a population based cohort by Lingam et al., (2010) found that children had an increased risk of difficulties in attention, short-term memory, academic and social skills if they also had DCD.

ASD and DCD are commonly reported comorbid. For example, Green, Baird et al. (2002) found that the incidence of motor impairments reported in the literature on ASD ranged from 73-90%. By using DSM IV criteria for ASD and DCD they tested a group of boys with Asperger's syndrome and a group with DCD, and reported that their motor performance was quite similar. Despite considerable variability being present in this group, the most severe cases of motor impairment were found in the Asperger's group and these boys clearly met the diagnostic criteria for both conditions.

Hill (2001) reviewed the literature on neurodevelopmental disorders of language and movement and concluded that there is substantial comorbidity between SLI and DCD. Gaines & Missiuna (2006) also found high comorbidity of SLI and DCD in kindergarten children and called for motor screening, as children with SLI appeared to be at greater risk of DCD than TDC.

DCD is commonly reported to be comorbid with ADHD. Indeed Kadesjo and Gillberg (2001) found, in a population based study in Sweden, that 87% of children who met full diagnosis for ADHD (DSM –III criteria) also had one or more comorbid diagnoses and 67% at least two diagnoses. The most common types of comorbidities reported with ADHD include oppositional defiant disorder; conduct disorder, affective and anxiety disorders, reading disorders and DCD (Kadesjo & Gillberg, 2001). In addition, Pearsall-Jones, Piek & Levy (2010)

found ADHD commonly associated with mood disorder. Therefore, it is possible that a child with DCD comorbid with ADHD could easily experience additional comorbidity. Although Martin, Piek et al. (2010), using latent class analysis, found that motor problems and ADHD were not found in the same class unless other disorders were also present. However, they did find a distinct class of children with motor only problems, but primarily associated with gross motor problems, they also found that fine motor problems appeared closely linked with reading problems rather than ADHD. Comorbidity is clearly prevalent in many developmental disorders including DCD, but more research is required to ascertain the exact nature of the association.

Summary

Co-morbidity is relatively common in developmental disorders and studies indicate that it can have deleterious effects, indicating that children with co-morbidities are likely to have more severe problems. Therefore, when examining the course and prognosis of DCD it is important to understand the course and prognosis of the disorders most likely to co-occur with DCD.

4.4.2.5 Evidence from the trajectories of other developmental disorders

DSM-IV specified three subtypes for ADHD, the combined, the inattentive, and the hyperactive/impulsive. Larsson et al. (2011) used data from a population based longitudinal twin study to examine the trajectories of these subtypes based on parent ratings. They found instability in the subtypes over time and children shifted from combined to inattentive and hyperactive to combined, which suggests that ADHD subtypes cannot be viewed as stable or discrete categories. Furthermore, a review of literature on attention problems and academic achievement concluded that inattentive ADHD is associated with poorer academic outcomes (Polderman et al., 2010). Thus the subtype category of ADHD in the formative school years may be of key importance.

Subtypes of DCD have not yet been agreed. However, because of the heterogeneity of both motor and non-motor symptoms and the vast differences

in severity, detailed records are required to help our understanding. It is vital that future research records these characteristics and those associated with co-occurring disorders, sometimes referred to as associated characteristics (AC), in order to establish an account of progression over time.

Previous research suggests that DCD does not have a uniform pattern of problems. However, empirical evidence supports the persistence of DCD through childhood into adulthood and is has been confirmed as a lifespan condition (Barnett, 2008). This provides another source of information about the course and outcome of DCD, as attention has turned to the experiences of people with DCD. Opportunity for first hand experiences of DCD symptoms, including those of co-occurring conditions, and the type of activity and participation restrictions that adults and children with DCD encounter can be used to inform better understanding of the nature and course of DCD and inform intervention.

4.5 Evidence from experiences of adolescents and adults with DCD and the importance of participation

Data emerging from experiences of adolescents and adults with DCD demonstrates that they encounter persistent difficulty in both motor and non-motor areas. For example, Kirby, Sugden, Beveridge & Edwards (2008) questioned students with DCD and other developmental conditions in Further and Higher Education. They found that students with DCD reported on going problems with writing and self-care and were more likely to live at home than other students. Students with DCD also reported non-motor difficulty such as executive function difficulties greater than those experienced by students with dyslexia. More recently, Kirby and colleagues developed the Adult Dyspraxia/DCD Checklist (ADC, Kirby, Edwards, Sugden & Rosenblum, 2010), a structured questionnaire for adults with DCD. Young adults (n=19) aged 17-25 years meeting DSM IV criteria for DCD were questioned with the ADC, and nearly all had continuing coordination difficulties affecting areas such as writing

fast, playing team games, driving and parking. They also reported executive function problems impacting areas such as money management and organizing belongings. Importantly, they also reported greater isolation, avoiding team games, avoiding going to clubs or dancing and 50% reported participating in leisure time alone (Kirby, Edwards & Sugden, 2011).

These studies not only highlight the persistent nature of DCD, but also the serious impact the motor and non-motor symptoms associated with it have restricting participation in the lives of young adults with DCD. Therefore, careful consideration needs to be given to outcomes that are relevant to children and adults with DCD for both intervention and research. The ICF provides a useful framework with which to approach this.

4.6 Participation as an outcome for children with DCD

The International Classification of Function, Disability and Health (ICF: WHO, 2001), emphasizes functional performance in real life contexts. Disability is not only considered in terms of impairment to body structures and functions, there is also a need to identify limitations in activity and restrictions in participation in different environments. The importance of this was discussed in chapter two. However, a systematic review by Magalheas, Cardoso & Missiuna (2011) examined activities and participation in children with DCD from 1995-2005 and found that the majority of articles focused on body functions of children with DCD. Many studies reported activity restriction, such as difficulty with handwriting (52%) and use of hands in the classroom (45%) and for self-care (47%). However, the most frequent activity limitations and participation restrictions reported were play related activities (74%), such as riding a bike, roller blading, using playground equipment and participating in free play. 54% reported problems with running, jumping, skiing, swimming and limited participation in organized sports, whilst 43% reported poor performance on ball games. Thus participation in physical activity appears to be the area of most restriction for children with DCD. Limited opportunity for self-generated movement practice puts children with DCD at a disadvantage in terms of their motor learning and motor development, from a dynamical systems perspective.

Examination of some of the factors discussed in the literature that influence participation in PA could be helpful.

4.6.1 Reduced participation in physical activity in children with DCD

It has frequently been reported that children with DCD are not as physically active as their typically developing peers (Cantell, Smyth & Ahonen, 1994; Hands & Larkin, 2002; Shoemaker & Kalverboer, 1994; Poulsen et al., 2008) and that the children have reported that they lack confidence in physical activity (Losse et al., 1991; Shoemaker & Kalverboer, 1994; Cantell, Smyth & Ahonen, 1994). Self-efficacy (belief in one's ability or competence) is thought to impact participation in PA. Cairney et al. (2006) suggested that these factors contribute to make children with DCD less likely to participate in physical activity and put them at future risk of hypo activity and the health risks associated with it. Cairney et al. (2005) found that children with DCD had lower self-efficacy in PA than TDC; however, this may not be a universal finding. Stodden et al. (2008) found developmental differences in self-efficacy, as discussed in chapter three. However, it is important to understand some of the underlying assumptions in perceived self-competence and how it relates to research in DCD.

4.6.2 Investigation of perceived self competence in physical activity in children with DCD

Bandura (1982) defined self-efficacy as the sense that is developed when children are successful completing a task and attribute their success to their own abilities. This sense helps them to persist to succeed in tasks, whilst children with low sense of self-efficacy tend not to persist to solve the problem. Harter (1987) developed a theory of competence motivation with similar assumptions. She suggested that the level of mastery of a skill, referred to as competence, can range from poor, through adequate to superior and so children's level of perceived competence affects their continued interest in a task and any further mastery attempts. A major goal of achievement behaviour is the feeling of competence.

Skinner & Piek (2001) used Harter's theory to test perceived competence in children with DCD. They predicted that children with DCD were likely to experience low perceptions of competence in physical domains, because they were likely to have experienced repeated failure at movement skills and, as a result, limit their physical activity, thereby limiting their opportunities for practice. They tested a school population of 8-10 year old and 12-14 year olds. Children with MABC score <15th percentile were included in DCD group and these were matched for age and gender with TDC >50th percentile MABC and all had IQ >80. They found, as predicted, the DCD group had lower perceived athletic competence, but also found they had lower perceived social support and higher state and trait anxiety than the control group. These findings suggest that their problems were more complex than perceived athletic competence alone. Perceived athletic competence (PAC) is the way in which children perceive their sports ability and athletic performance (Harter, 1982).

More studies also found lower perceived athletic competence in children with DCD (Losse et al., 1991; Silman et al., 2011; Cairney et al., 2005; Cocks et al., 2009; Poulsen et al., 2008; Shoemaker & Kalverboer, 1994; Cantell, Smyth & Ahonen, 1994). However, there are studies, such as (Pless et al., 2002), that do not report lower perceived athletic competence in children with DCD. Furthermore, some studies report no difference between the PAC of children with DCD and TDC (Noordstar et al., 2014; Fliers et al., 2010). It is therefore possible that the poor motor ability in children with DCD may not be the over riding influence for their PAC. It is important to investigate which others factors may have a positive influence on the PAC for children with DCD, as it is thought that children with higher PAC are more likely to engage in physical activity, and an understanding of these factors could inform intervention to improve their participation.

4.6.3 Evidence from investigation of determinants of activity in children with DCD

Cairney et al. (2005) suggested that the potential pathways linking DCD to reduced PA were unclear, but nevertheless important. They investigated the determinants of activity levels by using the a self rated questionnaire, the Children's Self perceptions of Adequacy in, and Predilection for Physical Activity (CSAPPA) Scale (Hay, 1992) and a physical activity scale with 44 children aged 9-14 years who scored below 10th percentile on BOTMP. Unfortunately, no other DCD criteria were tested and so referred to the children as probable DCD (pDCD). The findings suggested that 28% of the variance in children's PA was predicted by their generalized self-efficacy and DCD. Furthermore, they found children with pDCD had much lower generalized self-efficacy than TDC and that higher self-efficacy was associated with greater participation in free play and organized activities. It therefore appears that perceived self-efficacy could have an important role to play in participation in PA for children with DCD, but the exact nature of which is unclear.

Kwan, Cairney, Hay & Faught (2013), compared 13-14 year old boys with pDCD and control TDC and found pDCD had lower PA, but that their attitudes to PA only accounted for 25% of the variance. Interestingly, both studies found a similar level of variance suggesting the self-efficacy can be significant, but that the influence of other factors may be equally important in participation in PA for children with motor difficulties.

Summary

It is evident from the literature that participation in physical activity is problematic for children with DCD. What is less clear is which determinants are associated with more positive outcomes for participation in PA for children with DCD. However, it is clear that poor motor control is a barrier to participation and reasonable to assume that targeted intervention is likely to improve motor control. However, it is difficult to predict which children with DCD are more

likely to improve with intervention, as studies have reported mixed results. Intervention studies with DCD and longitudinal design have noted variable responses to treatment. The advantage longitudinal intervention studies have over cross sectional studies is that they provide opportunity for follow up after the intervention to determine which children have maintained any gains made during the intervention. It is however unclear whether intervention improves participation in PA for children with DCD.

4.7 Evidence from longitudinal intervention studies in DCD

It is difficult to predict which children with DCD will progress and are more likely to have a positive outcome. The motor outcomes appear to fall into one of three groups; those which improve to typically developing level, those children that improve but never reach typically developing level and those who continue to have severe motor impairment (Cantell et al, 2003; Geuze & Borger, 1993; Knuckey & Gubbay, 1983; Sugden & Chambers, 2006; Green et al, 2008). However, more interesting, perhaps in terms of future direction for research is the reported differential response to intervention of children with DCD. Three intervention studies are of particular note:

Sugden & Chambers (2006) followed 7-9 year old children (n=26), who met DSM IV criteria for DCD over a 4-year period until they were 10-13 years old. They used parent and teacher interventions, with an ecological approach, and noted that after intervention the group mean showed that the children had improved motor performance. However, intra-group analysis revealed that the children fell into three subgroups after intervention: some children improved and maintained their motor improvement to typically developing level (>15th percentile); some showed an uneven profile and improved but slipped back to the impaired motor range once intervention ceased and some children showed no motor improvement. Unfortunately, there was no control group of TDC and the presence of co-occurring disorders were not reported, but this study provided empirical evidence for the differential response to intervention by children with DCD.

Green et al (2008) studied subtypes of DCD, who met DSM IV criteria, and randomly allocated children (n=46) to intervention groups using a cognitive orientation to daily occupational performance approach (CO-OP, Missiuna et al., 2001) for a 20-week intervention. Children with disorders co-occurring with DCD were identified and their SES was also noted. They found that some children got worse or showed little or no improvement, either with or without intervention; some responded well to intervention, but of those children some had difficulty sustaining their improvement. The group with problems in all areas remained with the most difficulties even after intervention. Significantly, more children with a comorbid diagnosis (two thirds) did not make good progress. Furthermore, comparing clusters of subtypes provided limited predictability of who would make progress without intervention and only better verbal ability seemed to contribute to a better prognosis. Interestingly though, progress in motor skill appeared unrelated to initial severity or subtype, as they found that some children with a milder presentation did not necessarily improve without additional help, which appears to be counterintuitive and warrants further investigation. This is an important study, as it not only identified children who met criteria for DCD; it took into account co-occurring disorders and symptom severity in the data analysis and noted SES. However, it did not have a control group of TDC and did not account for developmental and environmental factors over the same period.

A differential response to treatment has also been reported in other studies. For example, Van der Waelvelde et al (2010) investigated motor stability in a group (n=49) of young clinic-referred children at risk of ASD, ADHD and DCD according to DSM IV TR criteria. All had IQ >70, motor ability ≤15th percentile and were aged 4-6 years at initial assessment on MABC. The group contained nine children born prematurely. They argued that most research on stability and change in motor ability in DCD had concentrated on children over six years and wanted to investigate younger children. However, not all the DSM criteria were fulfilled for DCD and so the children could only be grouped in those with ASD, ADHD and no diagnosis. Analysis of variance (ANOVA) was used to determine differences between the groups at baseline and post hoc analysis

found the group with ASD had the lowest motor performance. Change in motor ability was determined as the difference in MABC score between initial and subsequent measurement 2-3 years later. Some of the children had received therapy by the time they were re-tested and 22 children were no longer ≤15th centile MABC. Interestingly, they found that children who received no therapy improved significantly more than those who did receive therapy. They also found that the ASD group made the least motor progress and concluded that poor motor performance in young children was not always stable. Although they identified some children who met the criteria for both ADHD and ASD diagnosis, they did not analyse the results for comorbidity separately. Unfortunately, there was no TDC comparison group over the 2-3 year period and so developmental aspects could not be taken into account. As it was not a random sample and the power and effect size of the study were not quoted, it is difficult to extrapolate from the results to the wider population. However, the study did find differences in motor performance between the groups initially and at follow up and highlighted that children with ASD were at greatest risk of poor motor progression.

This led Reinhart and McGuinley to question that if problems are stable over time (e.g. performance on MABC) it may indicate fundamental disruption to brain circuitry and would thus be more pertinent to compensate or work around the problem or work with modalities less likely to be disrupted by these circuits (Reinhart & McGuinley, 2010). This obviously will have a large bearing on the direction of future research on the role and efficacy of intervention for motor interventions, but more studies are required accounting for the disorders comorbid with DCD.

Summary

Some children, despite intervention, do not show improvement and have persisting motor problems, which poses several questions. Does it depend on the initial motor severity of the disorder DCD, or do the comorbid conditions create additional problems? Is it dependent on the age at testing and the type of

tool used to measure the impairments, or does the reported improvement in adolescence for some children actually occur as they find ways round their difficulties? Are the primary problems of more importance than the secondary problems that arise from living with motor coordination problems? Does a supportive environment affect motor outcome by influencing perceived self competence or is it the individual characteristics of the child, such as IQ, or motivation that is more important? Is there a difference in their motor learning between subgroups of DCD?

These important questions require a comprehensive methodology grounded in coherent motor theory in order to attempt to unravel some of the complexity.

An ecological approach to examine the various levels of influence would be one way to address some of these questions, but first it would be helpful to review some of the current theoretical perspectives in DCD.

4.8 Theoretical perspectives in DCD research

Work on DCD has been conducted from two different perspectives; these are the cognitive neuroscience and ecological approaches. The cognitive neuroscience approach is concerned with understanding biological processes that underpin cognition and action in order to understand any causal relationship between brain function, cognition and behaviour (Wilson et al., 2013). Whereas the ecological approach is concerned with the dynamic interaction between the individual, the task and the environment, which result in particular levels of motor skill or movement patterns.

A tension exists between different theoretical approaches to the understanding of the underlying causes for DCD. Wade & Kazek (2018) argue that the DCD has a history of causation viewed through the lens of an information processing (IP) model, whereby the brain is viewed a computer or machine that processes information, as described in chapter three. Motor deficits seen in DCD, from this viewpoint, are assumed to emanate from deficits in this processing system, but that this overlooks other causal explanations (Wade & Kazek, 2018). That is, the deficits are assumed to lie within the child or adult with DCD and the

corresponding research focuses on the characteristics of the child and his or her motor and perceptual abilities. However, Geuze (2018) observes that strength of IP models is that they use a systems analysis approach to break down the system into functional parts that may be tested on functional limitations or deficits and these limitations are assumed to contribute to the deficits seen in DCD. Wade & Kazek (2018) argue that this constitutes a reductionist approach and despite burgeoning literature adopting this approach, they suggest that little empirical evidence supports a 'valid and reliable causation' for DCD (Wade & Kazek, 2018, p495).

In contrast, an alternative explanation for the underlying cause of the motor deficits seen in DCD is viewed from an ecological approach, which is supported by Wade & Kazek (2018). Here concepts are taken from the perception-action and dynamic systems literature, whereby progress in motor performance is viewed as being constraints led, with the task, the resources of the child or adult and the environment all dynamically interacting (Sugden, 2018). Thus the deficits seen in DCD may be viewed as context dependent. Indeed, Sugden asserts that the child is never the unit of analysis, always the child in context (Sugden, 2018), because the transactions between the three components of task, child and environment continually change throughout the learning process in a non-linear self-organizing fashion. The literature reviewed in this and the preceding chapters suggests that there are many possible determinants for the progression of motor performance in DCD and for participation in PA that occur at different levels of interaction between the child and environment.

Therefore, in order to approach an understanding of the nature of DCD, it's motor trajectory and corresponding participation levels of the children it is necessary to examine the context in which these occur. An ecological approach to study design would permit this. However, a consideration of how the findings may contribute to an understanding of the causal influences in DCD and fit with the wider knowledge base is also required. A theoretical framework can help situate this knowledge.

4.8.1 Theoretical framework

Diagnosis for DCD is not straightforward and a number of questions have been raised in this thesis about its identification, assessment, inclusion and exclusion, which have important ramifications for research, as previously discussed.

It is logical to assume that in order to research a condition one needs a group of individuals who have received a diagnosis. It sounds simple enough, but let us consider some implications of a child receiving a diagnosis of DCD. First, we must assume that diagnosis is valid, however, Morton takes issue with the current methods of diagnosis of developmental conditions. He suggests that a considerable amount rests upon a diagnosis such as the management, intervention and prognosis of a condition, and points out that, as a result either misdiagnosing or not diagnosing at all can carry equal dangers for a child (Morton, 2004). Furthermore, he suggests that current diagnostic systems such as the WHO ICD 10 (and also by implication the DSM5) are "unscientific" because they rely on a list of symptoms to categorize an individual rather than being based on any theoretical position about causation.

This leads to us to question the basis on which we have to diagnose children with DCD. In both ICD 10 and DSM5 we are provided with a list of criteria (mainly behavioural) but no explanation of possible causation. There is agreement that children with DCD are required to score below a level expected for their chronological age and measured intelligence on a standardized test of motor ability, however, different standardized tests have been shown to identify different groups of children (Spironello, Hay, Missiuna, Faught & Cairney, 2010; Cairney et al, 2009) which only serves to cause us to question further the basis for diagnosis. Furthermore, Morton suggests that behavioural manifestations are notoriously difficult to rely on because they may differ in different situations and tell us nothing about underlying cognition (Morton, 2004). We know that children diagnosed with DCD are expected to fall in the range of normal IQ (>70) but nothing is stipulated about their cognitive processes, yet researchers have reported a higher prevalence of specific learning difficulties, difficulties

with executive function (such as planning), difficulty with cross modal perception, to name a few, but to what extent should these be part of the diagnosis or might they represent different subgroups? Yet, as Morton (2004) reminds us, cognition has been shown to be important in the recognition and understanding of two other developmental disorders, namely deficits in theory of mind in autism and phonological processing problems in dyslexia. We also know that children with good intact intellectual abilities can circumvent their difficulties to some extent, for example children with dyslexia still have underlying problems yet learn to read (Snowling, 2008). Could this also be that case with children with good intact intellectual abilities and improvement in motor performance in DCD? This leads us then to question the importance of the role of learning and of what may constitute an appropriate supportive learning environment. Might there be critical stages in development or a particular type of environment that is facilitative?

There is also the important question of the high level of prevalence of co-occurring conditions with DCD. Take for example the high prevalence of co-occurring ADHD; we can hardly ignore the impact that up to 50% of children with DCD may also meet the diagnostic criteria for ADHD may have, as attention difficulties will inevitably interfere with learning of all kinds. Will the characteristics of a child with ADHD plus DCD and their functional outcomes be different to those of a child with DCD alone? Or the case of SLI, or indeed autistic spectrum disorder, where a high proportion of children with these conditions also exhibit motor impairment severe enough to meet the criteria for DCD, how will their characteristics and outcomes differ, if at all?

4.8.2 Morton's causal model

Morton (2004) suggests that we should trust clinical intuition where disorders are not seen merely as collections of randomly occurring symptoms and use a multi level theory to explain variability and severity of the disorder at a biological or cognitive level or behavioural level rather than relying on observations at the behavioural level. Morton offers his 'causal modelling approach' to understanding developmental disorders (see Morton, 2004). Hill (2006)

advocated using this approach to help understand both the within group heterogeneity in DCD and the characteristics that are prevalent and homogeneous across other disorders. As both the homogeneous and heterogeneous characteristics of children with DCD are key areas of concern, Morton's multi level theoretical approach to developmental disorders is an appropriate approach to underpin a study examining these issues. Sugden & Wade (2013, p244) modified Morton's causal model to encompass a dynamical systems approach to examine DCD. They proposed adapting the levels of interaction to biology, constraints and behaviour, and included two-way influences between experience and biological variables being mediated by constraints, see Fig. 4.1. This approach can help us consider some of the complex influences on the motor and other characteristics that present in DCD.

Pearsall-Jones et al. (2010b) suggested that causal pathways of developmental disorders are indeed complex and are a combination of genetic, epigenetic and environmental factors that evolve over time. It is therefore important that future research takes these various factors into account. Case study design is one method that is suited to capture multiple types of data.

Although there is a lot of data on DCD and some sparse longitudinal data, there is very little indeed looking at the combination of motor and other characteristics that may influence stability or otherwise of children with DCD.

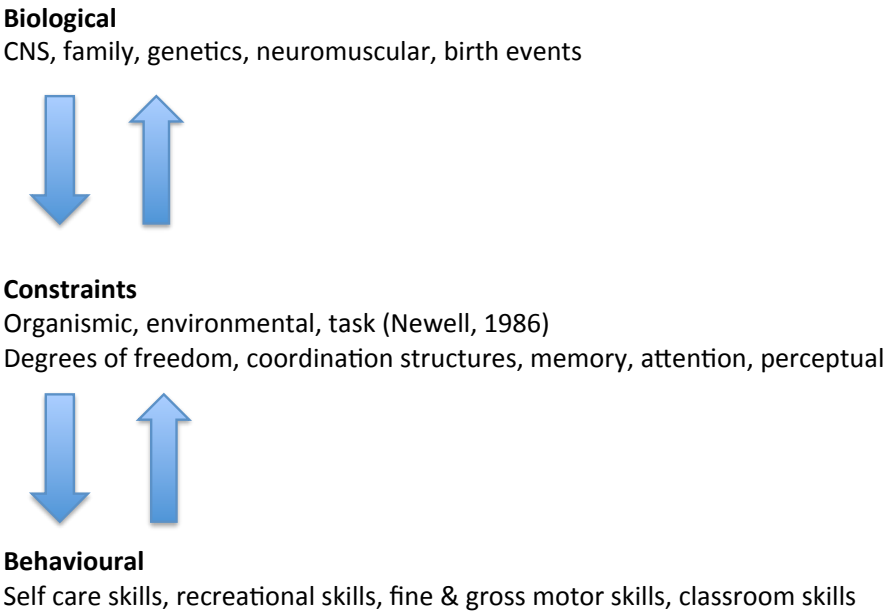


Figure 4-1 Proposed causal modelling of DCD (Sugden & Wade, 2013 p244, adapted from Morton, 2004)

4.9 Summary of current issues in DCD

Some of the complexity surrounding the identification, presentation, course and outcome of DCD has been considered in this thesis. The first complex issue concerns co-occurring conditions. Empirical evidence indicates that co-occurring conditions and their associated characteristics are common and can have a potential negative impact on the motor and non-motor outcomes for children with DCD. However, there is evidence to support that DCD does exist as a separate disorder in 'pure' form. It is therefore important to try to ascertain which outcomes relate to DCD and which are more likely to be attributed to the characteristics of co-occurring disorders.

The second concerns IQ, as IQ may also have a role to play in the outcomes for children with DCD. For example, at a biological level whether low IQ may indicate more severe difficulties, or limit response to experience because of

impaired learning. Closer investigation of IQ is required within the context of motor progression in DCD and should include observations of motor learning.

The third issue concerns the environment and the child's context. The role of the environment and environmental constraints have been discussed in relation to child development in general and motor development in particular, when considering a dynamical systems theoretical approach to motor progression in children with DCD. The emphasis from this approach is of observation of the child, the tasks and the child's context. The context includes determinants for PA, such as, opportunities for practice, family resources and attitude to PA.

The fourth concerns issues of measurement. The various tools for measurement of motor ability and their different cut off thresholds have come under scrutiny in DCD research, but without an understanding of the child's context, they are insufficient to fully understand the nature of DCD. However, the measuring tools and cut-off thresholds do need to be identified and noted in DCD research, as the children with different severities of motor impairment may have different trajectories and outcomes.

The fifth concerns variable outcomes within groups of children with DCD. Variable motor progress and large intra-group differences have been widely reported in empirical DCD research, which has led to investigation of subtypes of DCD, but with only limited success. It may be that motor variability is of importance and could potentially be used as a prognostic indicator for atypical development.

The sixth concerns response to intervention. Differential response to intervention has also been reported from empirical studies in DCD, the cause of which remains unclear. Literature indicates the potential importance of the role of genetic or biological difference, environmental constraints, the role of self-efficacy and opportunity for practice as factors for motor learning and motor

progress. These factors therefore need further exploration by careful systematic investigation in a natural environment, without intervention, in order to understand some of the differences between children with the different presentations of DCD and TDC.

Summary

Therefore, in order to help understand some of these influences in DCD, a systematic investigation of some of the components discussed using Bronfenbrenner's bio ecological model was undertaken. This provided a framework for data collection at different levels of interaction, so that subsequent analysis of motor progression from a dynamical systems approach to motor development could be attempted. The aim was to permit better understanding of the difference levels of influence on motor progression in children with DCD and of their experiences of participation in physical activity. Details of the study design and procedure are covered in the next chapter, but first the various methods of statistical data analysis require careful consideration. The method of analysis and interpretation of data are equally important, as the use of different methods of analysis can lead to different conclusions.

4.10 Considerations for data analysis in DCD research

4.10.1 Group comparison

A vast body of evidence has reported difference between children with DCD and TDC on a number of different perceptual and motor tasks, as discussed in chapter two. However, comparative study design comparing children with DCD and TDC has been criticized, as it fails to capture the variability in the performance of the children. For example, within group variability is widely reported in studies of children with DCD (Geuze et al., 2001; Sugden & Chambers, 2006; Green et al., 2008; King et al., 2011). However, group comparison between DCD and TDC, although they may be statistically different, do not tell us much about the heterogeneous individuals, or underlying causes (Cantin et al., 2014; King et al., 2011). Some authors have reported individual

differences within groups of children with DCD that include some children who perform worse than their peers, others at the same level as their peers and even some who perform better than their peers at some tasks (Sugden & Chambers, 2006; Green et al., 2008; Van Waelvelde et al., 2009). Cantin et al. (2014) observed that, as a consequence, when group means are calculated large standard deviations are often reported, which threatens the assumption of homogeneity of variance, which are required by the majority of statistical tests used in comparative study design. Furthermore, it is then difficult to know if the reported group differences are truly representative of the group or due to a few outliers (Cantin et al., 2014, p219).

4.10.2 Cluster analysis

Cluster analysis has been used repeatedly to investigate the heterogeneity within DCD and some limitations have been discussed previously in relation to prior research in DCD. King, Harring, Oliveira & Clark (2011, p1389) have further criticized the use of cluster analysis to describe the behavioural differences (sub-types) between groups based on relationships among multiple dependent measures for each individual, as it is sensitive to the measures chosen and therefore analysis/interpretation of subtypes is subjective. An analysis proffered in this paper is that, historically, the measures chosen in DCD studies have been influenced from an Information processing theory approach to motor development and the majority of studies have not taken account of the commonly co-occurring disorders.

4.10.3 Developmental landscape

Another approach is the ‘developmental landscape’ approach, which uses a large cross-sectional age range of TD children that form an age-based regression. DCD children outside the upper prediction limits of the TD regression are considered to have impaired performance on that task. This approach emphasizes individualized performance and it compares DCD children to a much larger group of TDC with a more expansive age range. However, it does not examine population level effects and differences at the

individual level may be difficult to detect if the between–subject variability of TDC is large (King, Harring, Oliveira & Clark, 2011, p1389).

4.10.4 Random coefficient models

An alternative approach to is to use random coefficient models, as they can better characterize intra- and inter- individual variability in children with and without DCD than general linear models (GLM) (King et al., 2011). One random coefficient model reported in DCD studies is multi-level modelling (MLM) (Cantin et al., 2014; Veldhuizen & Cairney, 2015). The advantages of this design are that data points are considered individually and in addition; multilevel modelling has less stringent assumptions than other statistical methods and so can be used, for example, even if homogeneity of variance is violated. It also has the potential to handle problems in research such as missing data and unbalanced longitudinal data (in that the number and times of observations may differ between individuals), and so may be a more convenient method of field analysis (Snijders & Bosker, 2002). Furthermore, Veldhuizen and Cairney (2015) advocated that multi level modelling provides the opportunity to study cases of marginal or fluctuating function. Indeed, researchers in the field of DCD are beginning to emphasize the importance of individualized analysis as a useful alternative (Bo, Bastian, Kagerer et al. 2008). However, in order to have sufficient statistical power in MLM large sample sizes are required (Field, 2018) and is complicated by the fact that power varies with a function of effect size and intra-class correlations, it differs for fixed effects versus random effects and it changes depending on the number of groups and the number of observations per group. Despite the advantages of MLM, it is difficult to recruit sufficient children who meet DSM5 criteria for a large sample size.

4.10.5 Analysis of longitudinal data and the problem of variability

Analysis of longitudinal study design poses yet more challenges. The nature of DCD, as a heterogeneous condition that occurs in early childhood, can be problematic when researching such a condition. It is well documented that child development is a complex interplay of genetic endowment, parenting, environmental experiences and the opportunities for learning over time (Smith,

Cowie & Blades, 2003; Hulme & Snowling, 2009). Hence a child's progress with DCD is difficult to predict and complex to study because of multiple stochastic variables. Longitudinal data is therefore very important in order to investigate factors involved in the influence of a child's progression, but data analysis must be able to capture these stochastic and multiple levels of influence.

There is a dearth of information about change over time for children with DCD and many complex methodological issues as discussed previously, which will impact on analysis. For example, Veldhuizen and Cairney (2015) highlighted that use of repeated testing in longitudinal research might result in cases that change to non-cases and vice-versa, from measurement to measurement. In addition, children with DCD have also often been reported to be variable in their trial-to-trial performance (Sugden & Chambers, 2006; King et al., 2011; Cantin et al., 2014), but when this is averaged over the trials the characteristic variation is lost. Cantin et al. (2014) highlighted that this intra-individual variation might be an important feature of DCD; as such changes could be different for children with DCD than for their peers. In this thesis it is argued that the intra-individual variability between children with different severities of DCD could be important, as changes could be different for children with DCD with more severe motor impairment than their less motor impaired peers or their typically developing peers.

4.10.6 Combining methods to augment data

One way to try to overcome some of the difficulties associated with each method of analysis is to combine methods to compensate for the shortcomings. For example, Sugden & Chambers (2006) chose both comparative study design using GLM statistics and individual case analysis to investigate group, subgroup and individual motor performance of children (n=26) with DCD pre- and post intervention over time. Whilst the comparative statistical analysis showed that there had been an overall improvement following intervention, the sub-group analysis based on motor percentile points on MABC, revealed important variable response to intervention, and the individual case analysis revealed idiosyncrasies with possible reasons for differential responses to intervention.

This study highlights how important data could easily be missed if the analysis relies solely on comparative design.

Summary

Each method for statistical analysis carries a potential drawback; whether it involves missing useful intra-individual data by the use of group mean data or limiting statistical power by using a sample size too small for a multi-level model statistical test. However, combining different approaches and augmenting data analysis facilitates a more holistic understanding and is less likely to miss important findings.

Finally, where there may be many determinants contributing to outcomes (such as motor development and the participation of children in PA), for example, parent attitude, school or social environment, they should be included in the analysis and defined as explanatory variables. However, they require a framework to facilitate a more holistic picture to be captured, analysed and interpreted. A case study approach that can combine different methods of data collection and analysis at different levels of interaction is one possible solution to this issue. Furthermore, Bronfenbrenner's bio ecological model lends itself to different levels of analysis, as previously discussed. Barnett (2008) summed up the notion of an integrated approach, when discussing comprehensive assessment of DCD, which could equally apply to research design and data analysis: "The assessor must be equipped with a sound understanding of motor development and DCD, knowledge of the basic psychometric principles and the ability to critically evaluate different assessments tools. A major challenge …will be to maintain an integrated approach to assessment across different levels of analysis. Methods that draw explicit links between biological, cognitive, behavioural and environmental influences will assist in this endeavour." Barnett (2008, p124).

CHAPTER 5 METHODOLOGY

Current literature has identified that the course of DCD is varied and that children with DCD may have very different motor outcomes over time, but it is not fully understood why. DCD is heterogeneous in nature and commonly co-occurs with other developmental disorders, but it is unclear whether children with DCD plus associated characteristics have poorer motor outcomes and participate less in physical activity (PA). However, children with DCD are reported to have poor self-perception of their motor ability and participate less in PA than typically developing children (TDC), but this may be context dependent. However, active self-generated movement is thought to be important for motor learning and so participation in physical activity is important for motor and general development. The aim of this study was to note each child's context and describe the different profiles of children with and without DCD and identify their stability or change in motor performance ability, alongside the consistency in the self-perception of their enjoyment, ability and predilection to participate in PA over time. This information was used to inform better understanding of the characteristics of the different severities of DCD and subsequent motor progression over time. The impact on the children's experience of participation in physical activity was also investigated, using the child's perspective.

5.1 Question: How do the profiles of children with DCD change over time?

5.1.1 What are the characteristics of children with different severities of DCD compared to children without DCD?

These included their:

- Motor characteristics
- Associated characteristics
- IQ
- Ability to take part in everyday activities

- Socio-economic and family context
- Self-perception of their adequacy, enjoyment and predilection to participate in physical activity

5.1.2.1 How stable are the motor characteristics or do they change over time?

5.1.2.2 How consistent are their self-perceptions of their adequacy, enjoyment and predilection to participate in physical activity or do they change over time?

5.1.3 How do the characteristics and stability or change in motor ability and self-perceptions impact experiences of participation in physical activity from the child's perspective?

To answer these questions a study was designed in three parts:

Part I identified and examined in fine detail the characteristics of children both with and without DCD. This included their motor performance ability, cognitive ability, demographic details and family characteristics, as well as their self-perceptions. The children were categorized into three groups according to the severity of their motor difficulties. These are the baseline data to enable comparison between the groups of children with different severities of DCD and typical children to answer the research question 5.1.1.

Part II examined how we look at the stability or change in the children's actual motor ability performance over time using three data points. It included a novel approach by concurrently examining the stability or change in the children's perception of their enjoyment, adequacy and predilection to take part in physical activity over time at the same three data points. This addressed both research questions 5.1.2.1 and 5.1.2.2.

Part III, using data from the previous two parts, examined whether the characteristics or whether their self-perception impacted on the experiences of the children with DCD to participate in physical activity. This information was

used to integrate the observations, measurements and different perspectives to inform better understanding of stability and change in the motor performance ability of DCD over time and the impact on participation in physical activity. The trajectories of selected case studies were analysed and supplemented with interview data to understand impact on participation in physical activity, from the child's perspective, and addressed question 5.1.3.

5.2 Design

The investigation adopted a three-part prospective longitudinal study combining quantitative and qualitative analyses to examine the presentation and progression of children with DCD and the impact it had on their experiences of participation in physical activity (PA). The design was ecological in nature, reflecting the importance of the complex nature of the bidirectional interaction of the environment with the characteristics of the child with DCD. The context (or ecology) in which a child develops is an important part of the developmental process and Bronfenbrenner (1977) argued that developing children influence the people and institutions around them as much as they receive influence from them. Indeed Sugden & Wade (2013) suggested that Bronfenbrenner has shown how the ecological settings are the major drivers of overall child development. The environmental settings can be thought of as a series of nested concentric circles, with the child influencing and being influenced by each of the various levels. The main focus of this study included settings in the first three levels. The settings include the first layer, which is the child's immediate family environment (which Bronfenbrenner refers to as the microsystem). The next layer comprises major settings at a particular point in life, e.g. school (referred to as the mesosystem) and the importance of the child's interactions here. The subsequent layer (the exosystem) refers to environmental factors that may be remote from the child, but nevertheless impact on the child's development e.g. parent employment or school special educational need (SEN) provision. Finally, the outer layer (the macrosystem) refers to external factors such as government policies and initiatives, the community cultural climate, the media's portrayal of gender roles etc. that influence the child's participation and development.

Bronfenbrenner enhanced his original ecological theory from the 1970's to include the role of the child's individual biology, psychology and behaviour fused dynamically with the ecological systems described; he termed this his Bioecological theory (Lerner, 2005). Morton (2004) took a similar stance, but also suggested that in developmental disorders the biological factors can play a limiting role and that the problems can be at the neural, biochemical and genetic levels, but that higher IQ may ameliorate underlying deficits. The study therefore incorporated measurement of IQ in all the participating children to take account of this. Lerner (2005) further elaborated that the adaptive relations between an active individual and his or her active and multilevel ecology constitute the driving force of human development. Therefore, a fine-grained analysis of the characteristics of all the children was undertaken, coupled with analysis of data surrounding their ecological interrelations. These included children with different severities of DCD, as well as those of typically developing children, to help our understanding of the nature and progression of DCD and how it may impact participation in physical activity.

The study design was implemented using Bronfenbrenner's theoretical framework, with data collected about the individual characteristics of each child supplemented by collection of their ecological data framed in the micro-, meso- and exosystem levels for subsequent analysis. Consequently, there were a number of different stakeholders in this study with a series of different roles to play in child development. These included and were not limited to the children's parents, siblings, friends, teachers, sports coaches and local community. Sugden (2014) argued that the accumulation of each role played by each stakeholder can have a profound impact on the overall outcomes for the child, if used to positive effect, and termed this the 'aggregation of marginal gains'. The converse could also be true, with small barriers at each ecological level accumulating to have a negative impact on overall development. It was therefore important to consider the roles and interactions of the children with and without DCD with the various ecological levels to determine potential impact on their development of motor ability and participation in PA.

Child self-perception and perceived self-competence are areas thought to be important for child participation in PA, as previously discussed in chapters two and four. Indeed, Poulson, Ziviani & Cuskelly (2007) found that self-appraisal of satisfaction and ability was an important mediating influence in the participation in physical activity and team sports for boys. Measures of child self-perception of participation in PA were thus repeatedly administered for all children during the study. Therefore, mixtures of quantitative and qualitative data from the child, the family and school contexts were included in levels of analysis within the study in order to address the research questions.

Morse's (1991) priority sequence model informed how the mixed study design was approached. Initial quantitative data from standardized assessment determined the categorization of the motor profiles of children, who were then followed up over time. A case study approach was adopted to examine stable and changing motor profiles of children from each of the initial categories and explore the nature of the children's characteristics and their ecological interactions.

A few children from each category were purposively sampled to interview about their experiences of participation in PA from their perspective. Morse (1991) termed this a 'Qant – Qual sequential mixed methods' design, which was adopted to inform purposive sampling for the interviews in this study. Furthermore, this study design included typically developing peers who were also assessed and followed up over time. Hulme & Snowling (2009) suggested that in order to understand the impact of a developmental disorder it is necessary to relate it to typical development. Therefore, the stability or change in motor development of typically developing peers was compared to those with varying profiles of DCD to more fully understand the impact of DCD.

Summary

This ecological study used a prospective longitudinal design, which carefully profiled both the children with DCD and children with typical motor development to answer research question 5.1.1. This was a novel approach, as previous

studies have not necessarily screened the children without DCD, as they are assumed to be typically developing. The study then documented their progression in motor performance ability, concurrently with their self-perception of motor performance, over time to answer question 5.1.2. Again, this was a novel approach as perceptions about participating in PA and observed motor performance have not been tracked simultaneously in DCD research. This also involved collecting (ecological) contextual data about their families, schools and community, along with parental attitudes to PA. Three repeated measures of the children's actual motor performance ability were recorded, whilst repeatedly surveying their perceptions about PA over time to explore their stability or change in relation to their context.

Finally, some children with particular patterns of profile and progression were chosen for more detailed case study. These children were assessed for a fourth time and individually interviewed about their experiences of participation in PA. These case studies provided richer contextual detail and insight into participation with DCD from the perspective of the child and this addressed question 5.1.3. To my knowledge this is the first study to profile children both with and without DCD for associated characteristics that commonly co-occur with DCD and to investigate both their self-perception of motor performance whilst measuring their actual motor performance ability over time, in order to better understand impact on participation.

5.3 Ethical approval

Ethical approval was obtained from Leeds University Research Ethics Committee. In addition the author obtained a National Health Service (NHS) research passport and an enhanced Disclosure and Barring Certificate in order to satisfy the requirements for working with children and vulnerable people.

5.4 Procedure

The procedure for the three-part study is outlined in the flow diagram figure 5.1 below and the steps are discussed in section 5.4.1 These will then be explained in more detail.

Analysis of parts 1, II and III contribute to an overall picture of the nature of DCD.

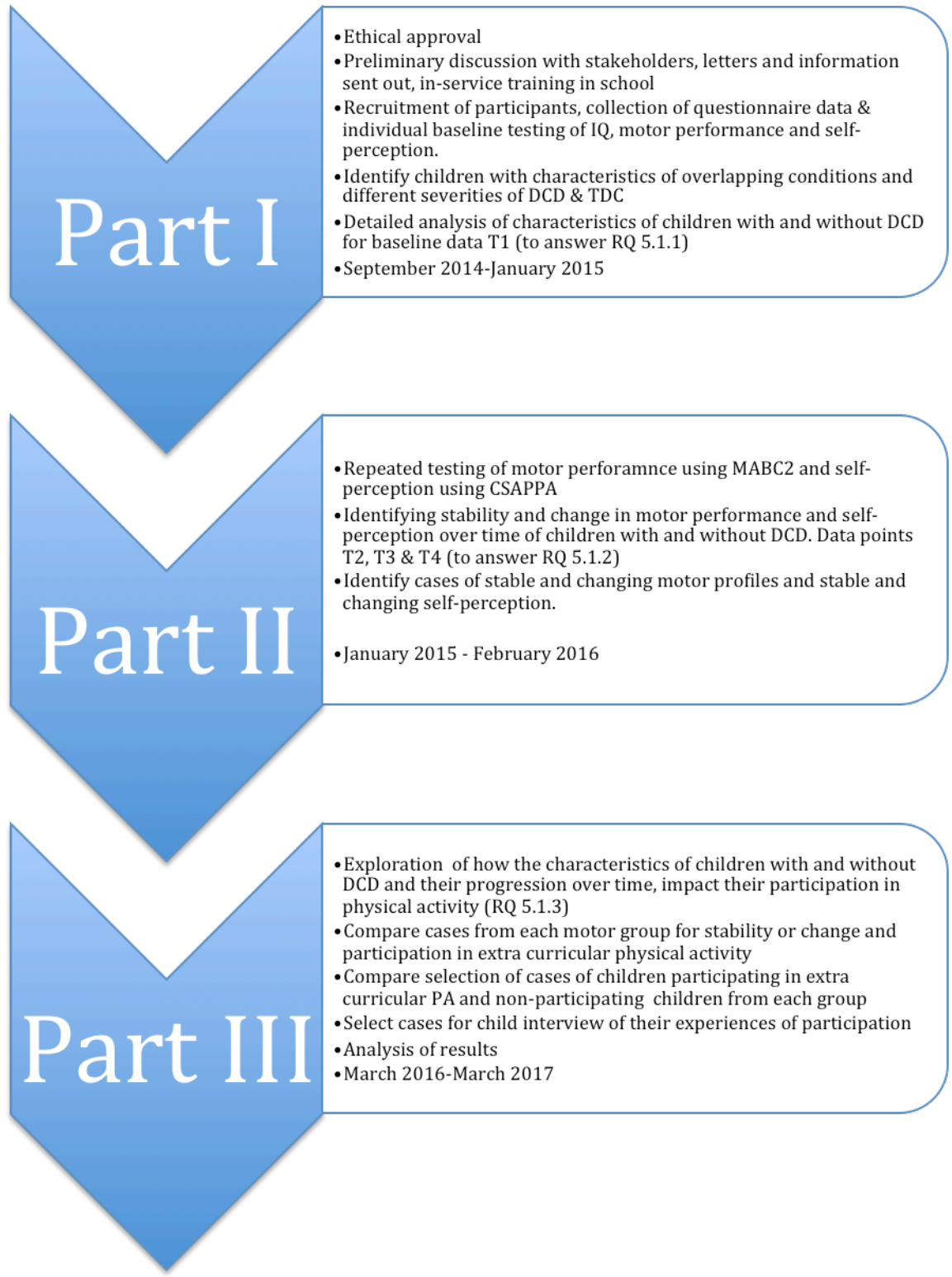


Figure 5-1 Flow diagram of the study procedure in three parts

5.4.1 Procedural steps

5.4.1.1 Preparatory work

Prior to data collection it was necessary to gain ethical approval and generate local interest with stakeholders. Ethics applications were made (see 5.3). Discussions with SENCOs, teacher advisors, Child Development Centre staff and the medical director ensued. They advised on schools potentially receptive to the project so that emails could be sent to head teachers inviting them to participate. Subsequent meetings were arranged to meet staff and deliver in-service training on DCD with participating schools. Handouts on DCD were given to teachers (see appendix 3) and information and consent forms were given to school SENCOs to distribute to parents (see appendix 4) along with researcher contact details should the parents have any queries.

5.4.1.2 Recruitment, baseline testing and classification

Experienced teachers identified typically developing children and their peers with movement difficulties but without a known medical diagnosis. Consent forms and questionnaires (see appendix 4 & 6) were sent to parents and returned via school SENCO. An experienced OT undertook individual baseline assessments (T1) and short summary reports of their child's results were sent to parents. The children were subsequently identified as those with and without movement problems and confirmed by Movement Assessment Battery for Children 2nd edition (MABC2). A comparison of the methods of identification by teacher, parent & MABC2 was performed. Classification by severity of motor impairment and the presence or absence of associated characteristics led to six classifications.

5.4.1.3 Repeat testing and analysis to inform sampling for cases and interviews

Repeat individual assessment of MABC2 & child self-report questionnaire (CSAPPA) (T2) was undertaken and analysis of results allowed tracking the children within group classifications. This was repeated again (T3). The profiles permitted purposive sampling of children for case studies and individual

interviews. A fourth repeat MABC2 and child self-report questionnaire (T4) were undertaken with the specific cases. Analysis of interview data combined with data from case studies and motor stability or change helped formulate a picture of DCD.

5.5 Ethical issues associated with the study

5.5.1 Consent

The schoolchildren were recruited via gatekeepers such as the head teacher and class teacher and there was a possible risk of coercion to participate. It should not be assumed that the children give their consent to participate by proxy; therefore, parent and child both need to give their consent (Alderson & Morrow, 2011). The children were therefore invited to give their assent in addition to written consent from their parents. Separate information sheets were available for the children, parents and teachers explaining the purpose and form of the research in terms that were understandable to each group. In addition, the author was available to answer any questions either in a group meeting or by email. All participants were also made aware that they could withdraw from the project at any time.

5.5.2 Wellbeing

The sessions of assessment were kept relatively short (around 60 minutes) and delivered in the format of ‘games’ to make them enjoyable. The children could take short breaks or stop at any time if they wished, in order to safeguard their wellbeing.

The nature of the assessments had the potential to highlight previously undiagnosed difficulties. There was a potential risk that families could feel that feedback about their child’s difficulties and support for the way forward might not be sufficient. Whilst this was not an intervention study, general advice about priorities for action at home and school was available and short summary reports for each child were sent home to ameliorate these potential difficulties.

5.5.3 Confidentiality

Children have the same rights to confidentiality as adults and consideration of storage of data from interviews on digital recordings and written notes and transcripts needed to comply with the Data Protection Act (Great Britain, 1998) (Alderson & Morrow, 2011). The participants were informed about the goals of the research and about dissemination of the outcome in the form of publications.

5.5.4 Privacy

Respect for privacy was important when collecting measurements, observations and particularly when interviewing, so a comfortable, quiet and private environment was negotiated with each school. It was made clear to the children that the interview could be stopped at any time. As the interviews involved questions about participation at school and with leisure, they could inevitably uncover aspects of the child's social and family life. Therefore, care was taken not to intrude on their right to privacy and only follow questions directly related to the research aims in accordance with the Data Protection Act (Great Britain, 1998). Time was spent building rapport with the interviewee, establishing mutual trust and explaining that names would change in published reports in order to protect privacy. It was also important that a summary of the research outcome was available in lay terms for all the participants to access the findings.

5.6 Recruitment procedure

5.6.1 Stakeholders

Extensive discussions took place with Local Authority Special Needs Coordinators (SENCO), specialist teacher advisors and staff from a Child Development Centre about the proposed project and about which stakeholders would be receptive to approach. During this period the NHS Trust underwent reorganization and a rapid turnover of senior staff, which made it impossible to engage the NHS Child Development Centre in the project.

5.6.2 Gatekeepers

Letters attached to emails were sent to head teachers outlining the project and inviting them to participate in the study. These were followed up with further emails and the offer of a face-to-face meeting with the researcher. Meetings were established with the responding head teachers and a short in-service presentation on DCD was arranged. This was followed up with brief handouts outlining the symptoms a child with DCD at primary school and a child with DCD at secondary school might encounter (appendix 3). Teachers were asked to identify children they suspected of having DCD (i.e. they did not have a known medical condition) and children who were their peers without movement problems or special educational needs. The parents were then given written information about the study (appendix 4) and invited to participate by the SENCO. All the parents that gave written consent for their children to participate were given a parent questionnaire (PQ) (appendix 6), and three screening questionnaires: the Developmental Coordination Disorder Questionnaire-revised (DCDQ '07) (Wilson, Kaplan, Crawford & Roberts, 2007), the Swanson, Nolan & Pelham–IV Questionnaire (SNAP IV) (Swanson et al., 2001) and the Child Communication Checklist 2nd edition (CCC2) (Bishop, 2003) and asked to return them via the SENCO. There were no financial incentives offered, but all the parents were presented with a brief summary report of their child's results.

5.6.3 Children's assent

Children were asked for assent to participate each time before being individually assessed by the author, an experienced occupational therapist, at school. Each child was assessed using the Kaufman Brief Intelligence Test 2nd edition (KBIT2) (Kaufman & Kaufman, 2004), the Movement Assessment Battery for Children 2nd edition (MABC2) (Henderson, Sugden & Barnett, 2007) and the Child Self Perceptions of Adequacy in and Predilection for Physical Activity Scale (CSAPPA) (Hay, 1992). All data were stored according to the Data Protection Act (Great Britain, 1998) and the results were anonymized. The data were collected by means of 3 or 4 repeated assessments over two

academic years by the same therapist. All tests were administered according to the standardized procedures outlined in the test manuals. The measures used are described in section 5.10

5.6.4 Case selection for interview

Children were classified at baseline into Red, Amber and Green groups using the traffic light system proposed in the Movement Assessment Battery for Children 2nd edition (MABC2) manual (Henderson, Sugden & Barnett, 2007), based on the percentile rank of the MABC2 total impairment the score. The process of classification of children at baseline is outlined in figure 5.2. The children's profiles and progression were then analysed in order to purposively sample specific cases to interview. The interviews were semi-structured and lasted 20-30 minutes. The interview schedule (appendix 7) included questions about participation in everyday activities and was informed by previous research (Dunford et al., 2005; Iverson et al., 2005; Mandich et al., 2003; Missiuna et al, 2006; Missiuna et al., 2007; Missiuna et al., 2008; Kirby et al., 2008; Lingam et al., 2013). The theoretical approach was phenomenological, aiming for the lived experience of DCD from the child's perspective. Semi-structured interviews with grand tour questions such as "tell what it is like…" were used to explore issues such as progress in school: friendships, academic strengths and weaknesses, differences, frustrations, triumphs and participation in sports and physical activity. In addition, the type, importance and enjoyment of leisure pursuits were explored along with issues with self-care and the problems and strategies adopted to overcome them. The interviews were enhanced using participatory arts-based materials depicting a series of activities including self-care, leisure and schoolwork to assist when conversation lapsed.

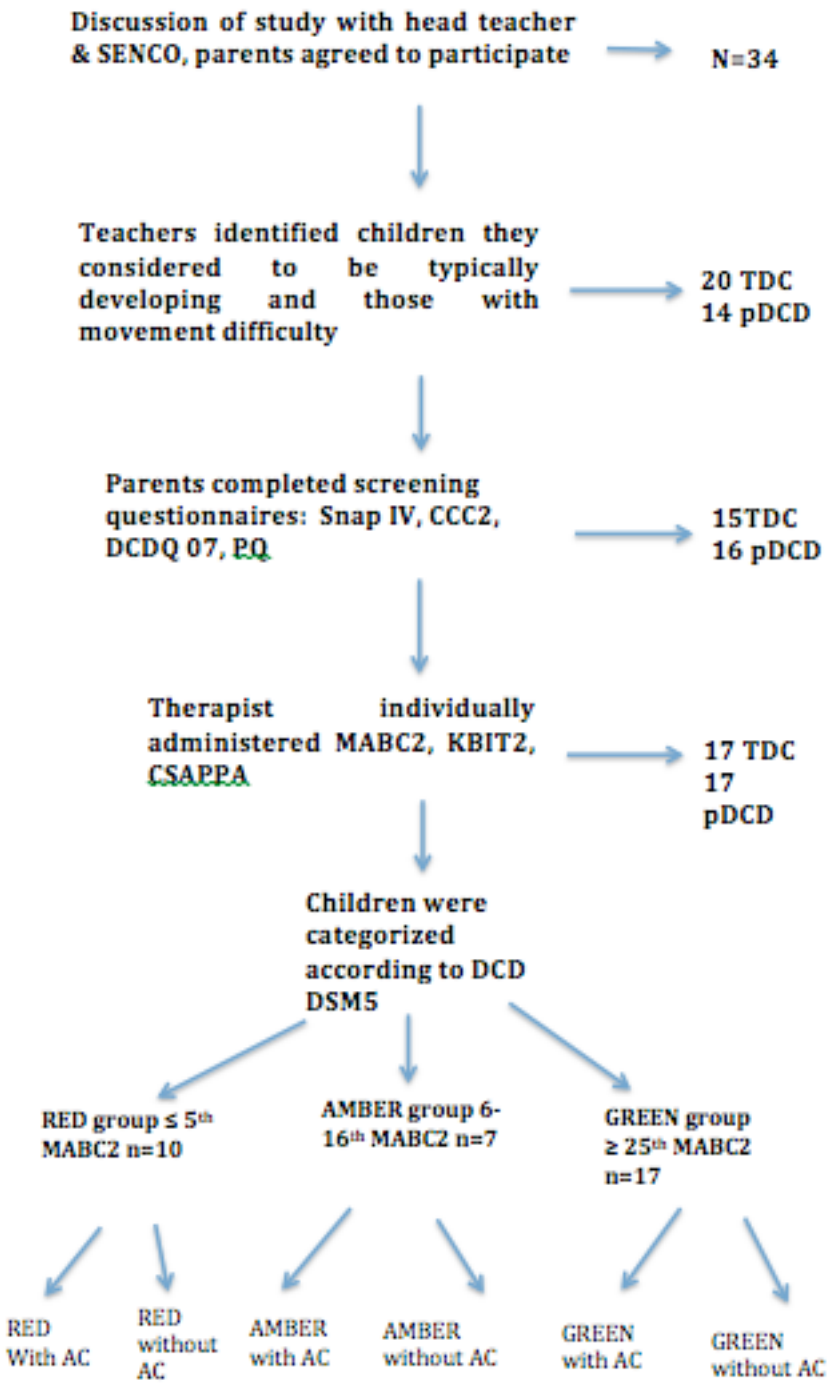
The children were informed at the beginning of the interview that they did not have to answer any questions that they did not want to and could stop the interview at any time. The interviews all took place at school; individually in a private room away from other children. The interviewer was the author, an experienced OT used to interacting with children with and without DCD. All

interviews were recorded verbatim with a digital voice recorder and transcribed. Additional field notes were also logged to note emotional tone or any special circumstances. Narrative data were thematically analysed. The Themes were coded independently by two researchers and then compared and revised until there was agreement. The themes were also compared to previous research to examine any commonalities.

5.7 Participants

A convenience sample of children was recruited from school populations, rather than clinic populations, in order to eliminate potential referral bias and to identify any undiagnosed children with DCD. Caron & Rutter (1991) found that clinic populations of children often have an increased prevalence of co-occurring conditions and more severe problems. This was further supported by Sinani et al. (2011), who found differences between school and clinic samples of children with DCD.

Figure 5-2 Recruitment and classification procedure



By using a school population it permitted the opportunity to identify children with DCD who may be coping or who are under the radar of services and explore the factors that may contribute to their successful participation.

As this was a convenience sample, additional contextual information about the families and any co-occurring characteristics of other developmental disorders (that are not exclusionary under DSM5 for the diagnosis of DCD) was required to facilitate meaningful interpretation of the results. After ethical approval was granted Head teachers and Special Needs Coordinators were initially contacted and invited to participate in the study. Then, after extensive discussion about DCD with the Special Needs Coordinators and Head teachers, parents were invited to participate in the study. Data were collected over two academic years from 34 children in mainstream schools (whose parents had given their consent). The children were recruited from both primary and secondary schools in order to include children pre and post- puberty and transition to secondary education.

5.7.1 Inclusion criteria

5.7.1.1 Inclusion criteria for Parts I, II

Teachers in mainstream schools identified children they considered to have motor difficulties and those they considered to be typically developing. Children from junior level and above were included, as they have developed more independence than those in infant level. Both girls and boys, between the ages of 7-14 years old at the start of the study, were invited to participate because these age groups are able to express themselves. To be classified as DCD the children normally meet the DSM5 (APA, 2013) criteria, which usually includes a diagnosis from a paediatrician after gathering information from multiple sources for each criterion.

Please refer to Table 2.3 in chapter Two for the DSM5 diagnostic criteria.

A criticism of previous DCD research has been lack of transparency about adherence to DCD diagnostic criteria (Geuze et al., 2001; Smits-Engelsman at al., 2015; Farhat et al., 2016), yet strict adherence may not always possible. For example, an assessment from a paediatrician is not always readily available in school population studies, but this should not excuse lack of transparency in the inclusion criteria. Therefore, in order to adhere to the DSM5 criteria as close as possible in this study, without an assessment from a paediatrician, the results from an occupational therapist, teachers, parents and the children themselves were consulted in the following ways detailed in table 5.1.

Please refer to table 5.1

The fifth percentile cut-off score was used in both the DCDQ (07) and CSAPPA to identify children with impairments and ensure optimum sensitivity. Sensitivity measures the proportion of positives that are correctly identified (i.e. those with DCD identified correctly), whereas specificity measures the proportion of negatives that are correctly identified (those without DCD correctly identified as not having DCD). APA (2000) suggest that in population based screening a sensitivity of 80% and a specificity of 90% is required in instruments used to screen for DCD. In addition DSM 5 (APA, 2013) recommends an individual standardized motor assessment for each child but, following the EACD guidelines (Blank et al., 2012), both ≤ 5^{th} percentile and 6-16^{th} percentile on MABC2 motor assessment were recommended. Therefore both were included to facilitate the identification of children with DCD.

Table 5.1 How DSM5 criteria were investigated in this study

Criterion	Diagnostic features
A	The author, an experienced Occupational Therapist (OT) individually assessed each child with the MABC2 (Henderson, Sugden & Barnett, 2007), followed by a discussion with the special needs coordinator to ascertain if the motor skills were substantially below that expected given child's chronological age & opportunity for skill learning and use.
B	The teacher identified children and the parents were invited to complete the DCDQ 07 (Wilson, Kaplan, Crawford & Roberts, 2007) to rate their child's movement ability in relation to everyday tasks to determine if the motor skill deficits in A significantly and persistently interfered with activities of daily living.
C	The parents and special needs coordinator confirmed that the onset was in the early developmental period and Parent questionnaires were completed to comment on their family history and circumstances.
D	The parents and special needs coordinator confirmed that there was no diagnosed visual impairment or neurological condition from school health notes (in lieu of a paediatrician assessment) and the Occupational Therapist assessed each child using the KBIT2 (Kaufman & Kaufman, 2004) to ascertain IQ scores.
Supplementary information (although not required under DSM5)	• The parents completed CCC2 (Bishop, 2003) and SNAP IV (Swanson et al., 2001) to screen for any associated characteristics in communication and attention. • The children were asked to rate their enjoyment and inclination to engage in physical activities by using the CSAPPA questionnaire (Hay, 1992).

5.7.1.2 Inclusion criteria for part III

Inclusion Part III (individual interviews):

The children selected for interviews were selected on the classification of their profiles at baseline and on their subsequent stable or changing motor profile overtime. At baseline the children were identified by the severity of their motor impairment and classified by the traffic light system proposed in the MABC2 manual (Henderson, Sugden & Barnett, 2007). Thus a child from each group (Red/severe, Amber/moderate & Green/typically developing, both with and without associated characteristics at baseline) was chosen to participate in an interview and describe their experiences of participation in physical activity (PA).

Table 5.2 Selection of children for interview based on classification

RED ≤5th percentile on MABC2	RED ≤5th percentile on MABC2 with AC	AMBER 6-16th percentile MABC2	AMBER 6-16th percentile MABC2 with AC	GREEN ≥ 25th percentile on MABC2	GREEN ≥ 25th percentile on MABC2 with AC
N=1	N=1	N=1	N=1	N=1	N=1

Some children did not remain in the same motor category over time and so an additional 4 children with unusual profiles, who changed categories over time, were also interviewed. This resulted in a total of 10 children who were interviewed. A more detailed explanation of the case selection is covered later in section 5.12.2 that discusses a framework for determining the cases.

5.7.2 Exclusion criteria

The exclusion criteria comprised any child with a general medical condition or neurological diagnosis, such as cerebral palsy, muscular dystrophy etc. or any

child with a visual impairment (DSM5, APA, 2013). This helped ensure not to attribute symptoms to DCD when they could be attributable to another condition. The exclusion criteria also excluded any child who did not attend a mainstream school, as the educational environment and level of support was considered too different to those in mainstream school. However, children attending an ASD unit attached to a mainstream school were included in the study.

It was decided not to include children below the age of 7 because they were not considered to be able to accurately express themselves in written self-perception questionnaires without a pictorial element (Missiuna, Pollack & Law, 2004). Children older than 14 years of age at the start of the study were also excluded; it was thought that the workload in preparation for external exams could possibly be disrupted by participation in repeated data collection over two academic years.

5.8 Summary of the study data collection procedure

Part I of the study involved teachers identifying children that they thought had movement difficulties and their peers who did not and who did not have any additional special educational needs. The teachers were briefed about DCD and given a handout detailing examples of how DCD may present at school. Parents, who consented to participate, completed a series of questionnaires about their child and family, but did not receive any prior briefing about DCD. Finally, an experienced qualified OT individually assessed each child at school. Parents and children received a short summary of their results. Part I of this study involved detailed analyses of this data collected at baseline.

Part II of the study entailed repeating the same motor assessment of the children in school by the same OT over two academic years and the analysis of any change in motor ability. Part II also involved repeated administration of a self-perception questionnaire with the children by the same OT, synchronous

with the motor assessments. In addition, all children were asked about their participation in extra curricular physical activity.

Finally in Part III analyses of child characteristics, motor stability or change and the stability or change of self-perception led to the identification of specific cases of children who were interviewed about their perceptions of participation in daily life and physical activity. This gave insights into some of the barriers and facilitators for participation in physical activity for children with DCD.

However, a crucial part of this study was consideration of each child's context. The context (or ecology) in which a child develops is an important part of the developmental process and Bronfenbrenner argues that developing children influence the people and institutions around them as much as they receive influence from them (Bronfenbrenner, 1977). Thus the complex nature of the characteristics of the developing child with DCD (biology, psychology and behaviour) and the dynamic interaction with the differentiated levels of the ecological system proposed by Bronfenbrenner's bio ecological model (Lerner, 2005) provide a useful model for levels of analysis in this study. There now follows an explanation of the various data requirements in order to undertake this analysis.

5.9 Detailed data requirements for analysis

5.9.1 Part I: identification, classification and profiling of schoolchildren

Part I provided analyses of the identification of schoolchildren by parents and teachers and the subsequent classification of children meeting the criteria in DSM5 (APA, 2013) using EACD guidelines (Blank et al., 2012) for DCD. Important detailed profiling of the children then followed the classification. This involved screening questionnaires, discussion with teaching staff and individual child assessments in order to compile a detailed profile of each child.

Information regarding commonly co-occurring characteristics of other developmental conditions, any medical conditions and special educational needs was also noted and analysed. The DCD population is known to be heterogeneous (Wright, 1997; Macnab et al., 2001; Hoare, 1994; Green & Baird, 2005; Visser, 2007; Green et al., 2008), yet little is known about how children with differing profiles progress. Therefore careful identification and fine grained analysis of each child's profile was undertaken in order to be able to differentiate the potential issues that could impact motor stability or change over time. The first of which was the severity of motor impairment.

5.9.1.1 Severity of motor impairment:

Previous studies have used different thresholds for the identification and inclusion as DCD making any comparisons difficult (see Smits-Engelsman et al., 2015). For example, it would be difficult to compare studies if they did not indicate whether they used children only in the lowest 5th percentile or those in lowest 6-16th percentile of motor ability on a standardized test, or whether both groups were amalgamated as one. As Geuze, Jongmans et al, (2001) suggested, the different cut- off scores used by different researchers poses problems in making inferences from the studies. Furthermore, Henderson & Barnett (1998) suggested this has potential far reaching consequences for clinical practice and education. This is particularly the case when examining developmental trajectories, as different levels of motor severity may experience different trajectories over time, especially important for any studies making claims about intervention effects. Therefore, children in this study were classified at baseline by motor severity to see if they exhibited differences in stability or change in motor ability over time.

However, different authors have suggested different methods of classification for severity of DCD. For example, Henderson, Sugden & Barnett (2007) proposed a traffic light system for scores on the MABC2 whereby children at or below the 5th percentile are identified in the red zone to have significant movement difficulty, those between the 5th -16th percentile are in the amber zone and are considered at risk of movement difficulty and require monitoring

and those above the 16th percentile are in the green zone and have no movement difficulty detected. Smits-Engelsman et al. (2015), on the other hand, proposed the classification of DCD as either severe or moderate DCD or typically developing for those groups respectively. Children in this study are classified by severity of their movement difficulties as follows:

Table 5.3 Classification of participant movement impairment

	≤ 5 th percentile	6-16th percentile	≥ 16th percentile
Smits-Engelsman et al. (2015)	Severe DCD (sDCD),	Moderate DCD (mDCD)	Potentially TDC (TDC)
Henderson et al. (2007)	Red	Amber	Green
	Significant movement difficulty	At risk, requires monitoring	No movement difficulty detected

It is of note that the Green or typical motor development group, should be referred to as potentially TDC, but will be classified as typically developing in this study. This is because they score on the typical range for motor ability but may exhibit other associated characteristics. In order to fully differentiate them from the other groups all children in this group scored ≥25th percentile on MABC2.

5.9.1.2 Co-occurring Characteristics:

It has been documented for some time that DCD co-occurs with other conditions, which led Kaplan et al. (1998) to suggest that it may not be a discrete disorder. However, DCD has been found to occur in pure form (Peters & Henderson, 2008). Nevertheless, Visser (2003) highlighted the importance

for future research to identify characteristics co-occurring with DCD so they could be investigated in terms of their developmental trajectories. This is salient since other research has identified that co-occurrence may lead to less favourable outcomes for children (Rasmussen & Gillberg, 2000; Germano et al., 2010; Cohen et al., 2000; Missiuna et al., 2011). Furthermore, Snowling (2008) argued that comorbidities must be explained and suggested that single deficit accounts for developmental disorders, such as dyslexia do not explain the heterogeneity observed. On a practical note, Kirby (2005) recognized the imperative to identify co-occurring conditions to facilitate effective management for individuals in both clinical and education settings. Indeed, Goulardins, Rigoli et al., (2015) described the comorbid occurrence of ADHD and DCD as a significant public health concern because of the increased risks of overweight, obesity and school achievement problems associated with both disorders. Therefore, screening for associated characteristics is an important aspect of the study. The associated characteristics chosen were difficulty with attention, social and language impairment. The instruments for screening these are described in section 5.10.

5.9.1.3 Measurement of IQ:

The co-occurrence of learning difficulty with developmental disorders has also been well documented (Dewey, Kaplan et al., 2002; Kadesjo & Gillberg, 1998; Germano et al., 2010 to name a few). Furthermore, Sugden & Wann (1987) found that children with moderate learning difficulties (IQ 50-70) were more likely to display movement difficulties, with findings that 30% of 8 year olds and 50% of 12 year olds in their study scored in the lowest 5th percentile of motor ability. DSM5 (APA, 2013), unlike ICD 10 (WHO, 1992), does not stipulate a minimum IQ level in the criteria for DCD, leading to the possibility of a diagnosis of DCD for children with IQ lower than 70 (providing they meet the other criteria). Moreover, the EACD guidelines do not stipulate a minimum IQ for diagnosis of DCD (Blank et al., 2012, p63). However, Sugden & Wade (2013) suggest that, as soon as IQ level falls below 70 the relationship between IQ and motor impairment rises as IQ falls, and for this reason should not be given a

primary diagnosis of DCD. However, many of these children commonly present to clinics with functional difficulties that impact on their daily lives and require some form of intervention. Therefore, it is important to ascertain if the motor impairment is over and above that expected for the level of intellectual impairment. Consequently, a profile of each child's level of verbal and non-verbal IQ was documented alongside their motor and functional ability at baseline. Thus ensuring that IQ could be taken into account, before drawing conclusions from the analyses of motor stability or change over time.

5.9.1.4 Data on SEN and handedness:

Impaired school performance is often associated with DCD in the extant literature, particularly with handwriting and may impact self-perception and participation. Furthermore Cairney et al. (2008) found higher prevalence of left-handedness in DCD ≤5th percentile and suggested a possible role for cerebral lateralization in motor coordination problems and so handedness was noted in this sample.

5.9.1.5 Contextual data about the family:

Another potentially problematic issue arising in the field of DCD is that of the heterogeneity and its potential underlying explanations, whether these occur within the child or are external to the child. Child development is generally now agreed to involve a dynamic interaction between the child and his or her environment (Smith, Cowie & Blades, 2003; Morton, 2004). This idea also follows that of the framework set out in the International Classification of Functioning, Disability and Health (WHO, 2001). Therefore, by identifying, measuring and classifying any associated characteristics, the severity of motor impairment and verbal and non-verbal IQ level, some baseline within-child measures were obtained for discrimination and comparison.

Contextual information about the resources available to each family were also collected in order to obtain data for each child to help explore factors external to

the child that could help explain motor outcomes over time and impact child participation. The parents were asked to complete questionnaires, which included information regarding socio-economic background, parent's employment, and number of children in the family, car ownership and family history of developmental disorders (King, Law et al. 2003; Michelson, 2006). These data were considered with respect to classification of the children for baseline data and for later comparison between them over time.

Beliefs, interests and attitudes also have an important impact on participation in physical activity (Jarus et al., 2011; Silman, Cairney et al., 2011) and so questions regarding importance of physical activity to the parents and how frequently they participated themselves were also included.

5.9.2 Part II: Stability and change in motor performance ability over time

Part II was designed to investigate the stability or change in motor characteristics of children with DCD over time. Geuze et al. (2001) highlighted the need for strict adherence to agreed DCD criteria in research to allow comparison between studies. Part I therefore provided detailed analyses of the profiles of the children with and without DCD. As previously mentioned, there is a dearth of information about the progression of differing profiles of children with DCD over time, with previous motor tests only standardized up to 12 years of age, raising the question of a ceiling effect in the reporting of change in older children with DCD. The Bruininks-Oseretski Tests of motor Proficiency (BOT-2) (Bruininks & Bruininks, 2005) and MABC2 are both now standardized up to and over 16 years of age, which permits follow up and examination of motor ability at secondary school age. The MABC2 was chosen for this study as it was standardized on a UK population. Thus, with well-defined research sub groups at baseline, the measurement of motor change was able to be analysed alongside the contextual data and associated characteristics to permit examination of factors likely to have contributed to the stability or change in motor performance.

5.9.2.1 Part II: Stability and change in child self perception of enjoyment, adequacy and predilection to take part in physical activity over time

Part II was designed to investigate the stability or change in the children's perception of their enjoyment, adequacy and predilection to take part in physical activity over time simultaneously with an objective measurement of their motor ability over time. This allowed a longitudinal comparison of their self-perceptions with their actual measured performance over time. Self-perception is thought to impact participation in physical activity for some children with DCD (Batey, Missiuna et al., 2014) but it is not clear if there are differential effects.

5.9.3 Part III Exploration of the impact of child characteristics, perceptions and motor stability or change on experiences of participation in physical activity

Analyses from part I, II and III of the study allowed investigation of any relationships between child self-perception and actual motor ability over time and allowed exploration of any differential impact of particular subgroup characteristics on children's participation in physical activity. This was then explored in more depth in a selection of individual interviews with children who possessed specific profiles and who demonstrated stability or change in motor ability over time. Post hoc analyses examined change over time and any differences between the groups of children with different severity of motor impairment. The more detailed analysis of the context of the selected case studies of the children with specific profiles, together with insights from their point of view, helped illuminate the findings and indicated factors most likely to have contributed to barriers or facilitators of participation in physical activity for the children with DCD.

5.10 Instruments

5.10.1 Measuring instruments for Part I: profiling children with and without DCD

5.10.1.1 Movement Assessment Battery for Children 2nd edition (MABC2) (Henderson, Sugden & Barnett, 2007)

The MABC2 is the test most commonly used to measure motor performance in DCD, is the best examined (Blank et al., 2012, p71) and has good reliability and validity, which is why it was chosen for this study. It served two purposes in this study; the first was to identify the severity and extent of motor impairment for profiling the children with and without DCD and the second was to measure change in their motor performance ability over time.

Identifying severity of motor impairment:

This is a test to identify children with motor function impairment aged 3-16 years and takes 20-40 minutes to administer individually. The total test score provides a measure of motor performance, which can help identify any difficulties under criterion A of DCD DSM5 (APA, 2013). The second edition extends the upper age range from 12 to 16 years, permitting assessment of adolescent schoolchildren. It has three subscales for: manual dexterity, aiming and catching and balance. Although Brown and Lelor (2009) questioned the validity of the MABC2 it was subsequently confirmed by confirmatory factor analysis (Schulz et al., 2011).

Przysucha et al. (2016) and Holm et al. (2013) have both questioned the test re-test reliability of age band two when using the total test score. However, Schulz and colleagues (2011) determined that the validity of the test becomes stronger with older children. This means that the profile of scores across the three subcomponents can be used with greater confidence in age bands two and three (Schulz et al., 2011). These two age bands were used exclusively in this study permitting an analysis of the motor profile of the children. Item scores can be converted to standard scores (mean =10; SD = 3). The total test score can

be calculated by adding the sum of the 8 item standard scores and then a standard score can be obtained (mean =10, SD = 3) (Henderson, Sugden & Barnett, 2007).

The inter–rater reliability .79, intra- rater reliability .79 and test –retest reliability (.73 to .92) of MABC2 are good to excellent (Henderson, Sugden & Barnett, 2007). Validity is also good (Schulz et al., 2011; Ellinoudis et al., 2011).

5.10.1.2 Developmental Coordination Disorder Questionnaire- revised (DCDQ '07) (Wilson, Kaplan, Crawford & Roberts, 2007)

This screening instrument was chosen to fulfil criterion B in DSM5, as it asks parents about the impact of their child's motor difficulties on everyday life.

The revised DCDQ is a 15 item parent-completed measure designed to identify subtle motor problems in children, originally for children 5-15 years old. It requires parents to compare their child's motor coordination for functional skills in everyday contextual areas with typically developing peers of the same age. It takes about 5 minutes to complete and is therefore a useful tool to help identify issues relating to criterion B in DSM5 (APA, 2013) for DCD. Wilson, Crawford, Green et al. (2009) state that the internal consistency is high (α = .94) and concurrent validity with MABC is acceptable (r= .55). A later study by Pannekoek et al. (2012) also found high internal consistency (α = .95) and concurrent validity with the MABC2 as fair but significant (r=. 34, p=0.01). The test authors state that the overall quoted sensitivity = 85% and specificity = 71%, although separate cut- off scores have been developed for three age groups (see table 5.4). Total scores range from 15-75 with cut off scores to support 'suspect DCD' and 'probably not DCD'. A higher score on the DCDQ '07 indicates a higher performance level. Three factors were originally identified but confirmatory factor analysis fit was poor, as a number of items had substantial loadings on more than one factor (Cairney et al, 2008). This led Cairney and colleagues to advise that it is best used as a measure of general motor problems and not to discriminate between the different kinds of problems (Cairney et al, 2008), which are myriad in DCD given its heterogenic nature. Only the DCDQ total score has been found to be a predictor of DCD (Cairney et

al, 2008) and so none of the sub scores and only the total score was used in this study.

A large population based study in Canada found both sex and age differences in their sample, with girls and older aged children having higher mean scores on the DCDQ (Rivard et al., 2014), which caused them to suggest separate norms were warranted. Interestingly Rivard et al., (2014) found the mean score sex difference to be more pronounced in the ≤5th percentile (boys to girls ratio of 2:1) compared with ≥25th percentile (boys to girls ration 1:1). Nevertheless, this Canadian study also confirmed the three-factor structure and the psychometric properties already reported (Rivard et al., 2014).

Table 5.4 Total DCDQ '07 score predictor of DCD status used in this study

Age	Cut off	Sensitivity (DCD correctly id)	Specificity (id correctly non DCD)
<8 years	≤46	75%	71%
8-10 years	≤55	89%	67%
>10 years	≤57	89%	76%
Overall ages	≤53	85%	71%

(Wilson, et al., 2009)

However, as APA (2000) suggest 80% sensitivity is preferable, 90% specificity is preferred for diagnostic test (Wilson et al, 2009), the DCDQ'07 does not meet the standards for sensitivity for children under 8 years. Neither does it meet the specificity criteria for a diagnostic test for DCD. This was also confirmed in an Australian study of adolescents aged 12-15 years, with findings of high sensitivity (85%) and low specificity (77%) (Pannekoek et al., 2012). Furthermore, in a review of parent and or teacher questionnaires commonly used to assess participation in children with DCD, Kaiser, Albaret and Cantell

(2015) found the results for DCDQ'07 in the different studies 'divergent and inconclusive'. As a result they called for more psychometric and cultural validation to confirm DCD. Despite it's shortcomings, the DCDQ 07 is a useful screening tool, provided it forms part of a two-step identification process for DCD, and is followed by an individual motor assessment to confirm or refute the diagnosis such as the procedure described by Wright & Sugden (1996). In this study parents, and in some cases where questionnaires were not returned, teachers completed the questionnaire and the total score was used to screen the children for possible DCD and then the children were individually assessed using the MABC2.

5.10.1.3 The Children's Communication Checklist 2nd edition (CCC-2) (Bishop, 2003)

This test was chosen as a screening tool for the associated characteristics of either or language and pragmatic impairments in children.

This is a 70-item multiple-choice questionnaire that screens for communication problems in children aged 4-16 years. It is standardized for a UK population and usually takes 5-15 minutes to complete. Its purpose is to screen for language impairment, identify pragmatic impairments in children with communication problems and assist in identifying children who may merit further assessment for ASD (Bishop, 2003). By definition pragmatic language impairments are dependent upon context and therefore information from someone who can observe the child frequently over a long period of time is required (Bishop, 2003). An adult, who has regular contact with the child, usually a parent or teacher, therefore completes the CCC2.

The checklist is divided into 10 scales, each with descriptions of strengths and difficulties and a rating of the frequency with which the behaviours occur. The first four scales are associated with specific language impairment (SLI); the next four cover pragmatic aspects of communication and the last two scales assess social relations and interests (behaviours that are associated with ASD). It is

possible to derive a Social Interaction Deviance Composite (SIDC), which reflects a mismatch between the sums of different scales to help identify a communication profile characteristic of autism. The CCC2 is able to discriminate children with communication impairments from a typically developing population, suggesting it is a useful screening tool (Norbury et al., 2004)

It is highly possible that children with DCD could have co-occurring SLI or ASD and this checklist provides a quick screening tool to help identify characteristics associated with both these developmental disorders. In this study parents or teachers who knew the child well completed the checklist to screen for characteristics associated with SLI and ASD at baseline.

The CCC2 has robust reliability, with internal consistency scores ranging from .65 to .8 across all scales (Bishop, 2003) and the strongest subtest inter-rater reliability (r=0.79) with the Social Interaction Deviance Composite (Norbury et al., 2004). Thus the checklist was considered robust enough to distinguish children with communication characteristics associated with ASD and SLI for the purposes of this study.

5.10.1.4 Swanson Nolan and Pelham - IV Questionnaire (SNAP IV) (Swanson et al., 2001)

This screening test was chosen to identify any associated characteristics of attention and behavioural difficulties in children.

The long form SNAP IV assesses ADHD, oppositional defiant disorder (ODD) and overlapping symptoms of other psychiatric disorders of childhood listed in DSM –IV and is available at http://www.ADHD.net. A short 26 item SNAP-IV version, also referred to as the MTA version, assesses ADHD core symptoms of hyperactivity/impulsivity and inattention, along with symptoms of ODD. There are average rating indices for inattentive, hyperactive/impulsive, combined ADHD and ODD subscales, where only scores above the 95th percentile are labelled clinically relevant (Bussing et al., 2008).

The 26 item SNAP–IV include 18 ADHD symptoms (9 for inattention, 9 for hyperactive/impulsive) and 8 ODD symptoms specified in DSM –IV. Items are rated on a four-point scale 0 (not at all) to 3 (very much) to obtain subscale scores for inattention, hyperactivity/impulsivity and oppositional defiance domains. The SNAP-IV is a reliable checklist with coefficient alpha for overall parent ratings α =.94 and coefficient alpha for each of the subdomains ranging from .79 to .90. (Bussing et al., 2008).

Table 5.5 Reliability coefficient scores for subdomains of SNAP IV

Sub-domain	Parent rating	Teacher rating
Inattentive	0.90	0.97
Hyperactive/impulsive	0.79	0.92
ODD	0.89	0.96

Bussing et al. (2008) also found that it has an acceptable internal consistency and 3-factor structure. Furthermore, the predictive validity of the SNAP-IV was found to accurately identify children with ADHD when parents score inattention above 1.8 and hyperactivity/impulsivity above 2.4 (Bussing et al., 2008). However the SNAP-IV ratings must be interpreted with caution, as they are not diagnostic in isolation and the test was normed on a US population (Bussing et al., 2008), but it was felt to be an appropriate screening tool for use in this study.

The scoring instructions are available at http://www.ADHD.net/snap-iv-instructions.pdf and the cut off scores used in this study are in the table 5.6.

Table 5.6 Cut-off scores for subdomains of SNAP IV used in this study

Sub domain	Parent rating	Teacher rating
ADHD inattention	1.78	2.56
ADHD hyperactivity/imp	1.44	1.78
ODD	1.88	1.38

5.10.1.5 Kaufman Brief Intelligence Test Second Edition (KBIT2) (Kaufman & Kaufman, 2004)

This test was chosen to identify children with learning difficulties and to differentiate those with greater difficulties in either the verbal on non-verbal domains. This test is an individually administered, brief measure of verbal and nonverbal intelligence for ages 4-90 years old, but is not a substitute for a more comprehensive measure (Kaufman & Kaufman, 2004). It was normed on a large population in the USA but was considered appropriate for use in this study, with a UK population, because the purpose was to identify children with potential learning difficulties rather than give a definitive assessment of intelligence or diagnosis.

It takes 15-30 minutes to administer. The verbal score contains two subtests, verbal knowledge and riddles. Verbal knowledge is a 60-item measure of receptive vocabulary and range of general information, which is delivered through an array of pictures, and the child had to point to their chosen response. The Riddles subtest is a 48-item measure of verbal comprehension, vocabulary knowledge and reasoning. Responses are either by pointing to a picture or by single word. The raw scores of the two subtests are added to give the verbal raw score. The non-verbal subtest, Matrices, is a 46-item non-verbal measure consisting of visual stimuli that require an understanding of the relationship between them. The child has to select the picture that fits best with the stimulus picture, some are abstract and some are everyday items. This section demands nonverbal reasoning and flexibility to problem solve.

It was chosen for this study because it is a robust assessment. The construct validity is reported to be good and correlates with the Wechsler intelligence scale for children (WISC) full scale IQ (Kaufman & Kaufman, 2004). Furthermore, the reliability coefficients quoted in the KBIT2 manual are high: Internal reliability for the verbal score for children and adolescents is .9 and for the nonverbal score is .86 (Kaufman & Kaufman, 2004). The reliability of the IQ composite score is .93 across the entire age range and the test re-test reliability is .91 for verbal and .83 for nonverbal, making it a robust test (Kaufman & Kaufman, 2004). However, the results have to be interpreted with caution on a UK population, because it was normed on a US population and there may be subtle cultural differences. Nonetheless, it was able to give a good estimate of each child's level of verbal and nonverbal cognitive function and identify potential learning difficulties for this study.

5.10.1.6 Parent Questionnaire

This is an 11-item questionnaire for parents, designed by the author using Burgess' guidelines (2001), to ascertain detail of family life. A questionnaire that covers items thought to be associated with child participation; as well as family history of developmental disorder and markers of socio-economic status does not currently exist. Rather than burden the parents with numerous questionnaires and risk a poor response rate, one questionnaire that covered all the desired areas was deemed more likely to be returned. The construct underlying the development of the questionnaire was the influence of parental factors associated with child participation in PA, based on current literature. Welk, Wood & Morss (2003) suggested that two aspects of parental behaviour promote PA in children. The first concerns role modelling, where a parent has an interest in PA, as well as their own efforts to be active. The second is parental support, which includes encouragement by providing opportunities for the child to be active such as participating in PA with the child or transporting the child to parks or leisure areas. It was therefore important to capture this data because of the potential impact on children's participation in PA in the study and to help answer research question 5.1.3. Furthermore, familial and

environmental factors have been found to influence children's PA. Levels of parent's education and income are particularly important factors (Zecevic, Tremblay, Losvin & Michel, 2010) and so these areas were also included in the questionnaire design.

The content of the first part of the questionnaire covers the family environmental factors. Items 1-8 require a tick box response and cover information about family history of developmental disorder, number of adults and children living at home, any parental health problems, parental employment status and indicators of resources available to the family, namely: maternal level of education, entitlement to free school meals and car ownership. The list was informed by findings from previous studies on participation by children with disabilities (King, Law et al. 2003; Michelson, 2006).

The second part of the questionnaire concerns parental attitude and support for PA. Items 9 & 11 involved parents ranking importance of physical activity (PA) to the family and the level that their child's coordination difficulty interferes with family life using a Likert scale: 1= not very to 4= very much. Item 10 asked the parents to rank how frequently they participated in PA on a 5 point scale, ranging from rarely to twice weekly. The questionnaire took less than 10 minutes to administer and provided a quick method to collect some data about each child's micro- and meso- system environments to supplement the ecological study design.

Whilst the questionnaire was not standardized and has no psychometric properties, it was piloted on two families in order to clarify the questions and subsequent changes were made before using it in the study. It was found to have ecological validity and was a useful tool to collect contextual data such as family history, parental attitude, numerical data on the family socio economic status and family environment, without having to use multiple pre-exiting questionnaires to collect all the data, thereby reducing the risk of non-response.

5.10.2 Instrument for Part II: measuring motor stability and change over time

5.10.2.1 Movement Assessment Battery for Children 2nd edition (MABC2) (Henderson, Sugden & Barnett, 2007)

Measuring change in motor performance ability:

The total test score from MABC2 was used to measure change in motor performance ability. However, as test scores only represents a snapshot of motor ability at time of testing there is some contention as to whether a change in total test score represents a detectable change in motor performance in everyday life or is possibly a measurement anomaly. Wuang et al. (2012) suggested that there is little consensus on how responsiveness in the MABC2 should be assessed and proposed to investigate this by means of internal and external responsiveness. They described internal responsiveness as the ability of a measure to change during a defined period and external responsiveness as the extent to which changes in the measure correspond to changes in a reference measure. The latter leads to the notion of the minimal important difference (MID) or smallest change in score that a client perceives as important (Wuang et al., 2012).

Motor change in this study was measured by the changes in the total score of the MABC2, but a decision was needed to identify the magnitude of meaningful change. Previous studies in DCD have reported the minimum important difference (MID) expressed as point changes in total test score. For example, Wuang et al. (2012) chose MID of a 2-point change in Total Test Score in a study for Taiwanese children. Wilson et al. (2016) chose another method to measure change in total test score post intervention, which they called the smallest detectable difference (SDD) and calculated it as SDD= 1.96 x √ (2 x SEM).

One way of ameliorating measurement anomaly is to be aware of the standard error of measurement of a test. The standard error of measurement for the MABC2 total score at the 90% confidence interval (CI) is two and is three points at the 95% CI (Henderson, Barnett & Sugden, 2007, p136). Thus in order to assume that the measurements avoid any error, a change of greater than three points in MABC2 total test score was required. However, this may still not guarantee a detectable change in everyday motor behaviour.

Holm et al. (2013) described another method that encompassed detectable motor behaviour change whilst still referring to MABC2 test scores, and referred to it as the smallest detectable change (SDC). Holm et al., (2013) define the SDC as the magnitude of change necessary to exceed the measurement error and represent the smallest change that can be detected beyond the measurement error. Their study results indicated that a change of +/- 10 total score points, with MABC2 level two, was necessary to state that real change had taken place using the same assessor over two occasions with Norwegian children (Holm et al., 2013). The 10-point difference reduced the possibility of measurement error, enhanced the reliability of the results, is more rigorous and was therefore adopted in this study to determine motor change.

An alternative approach, in a Dutch study, used standard scores and operated a change in standard score of two points using Dutch norms (Ferguson et al. 2013), but this approach would not be appropriate for UK children as Dutch norms were used.

Therefore, change in motor performance over time in this study was reported as MABC2 total score, with an associated percentile rank in relation to age norms. High MABC2 total scores indicate a higher level of motor ability on this test and the children had data on their motor ability collected at T1 (baseline), T2 and T3. Change scores were calculated for each child as the difference between MABC2 total score at baseline (T1), (T2) and (T3). Therefore, to examine any change during the study T1 scores were subtracted from T3 scores; positive score indicated an improved performance and a negative score indicated

deterioration in performance. This approach was similar to that adopted by Wilson et al. (2016) who measured change using the MABC. Finally, in order to examine inter-individual change in motor outcome over time during this study, T1 scores were subtracted from T3 scores and comparisons were made for each child in addition to those for each group.

5.10.3 Instrument for measuring stability and change in perception over time

5.10.3.1 The Children's Self-perceptions of Adequacy in and Predilection for Physical Activity scale (CSAPPA) (Hay, 1992)

This self-report for children was chosen as it may provide an idea of how each child perceives their own motor performance and has been the subject of a number of 'encouraging studies' (Blank et al., 2012, p69).

The CSAPPA 20 item scale is designed to measure children's perceptions of their enjoyment of, adequacy in and likelihood of engaging in physical activity. It takes 5-10 minutes to complete and can be administered individually or in a group.

This questionnaire is designed for children 8-16 years old and consists of opposing pairs of statements for the child to choose which best describes them and indicate whether the sentence was "sort of true for me" or "really true for me"(Hay, 1992). The most inactive or inadequate response is scored at 1 and the most active is scored at 4. It has strong predictive and construct validity and importantly, for use in this study, high test re-test reliability (r=.84 to .90) (Hay et al., 2004). It was found to significantly correlate with aerobic fitness, physical activity and motor proficiency (Cairney et al., 2005; Cairney et al., 2006). Internal consistencies are high (Cairney, Missiuna, Veldhuizen & Wilson, 2008) see table 5.7. Separate cut-off scores are recommended for boys and girls if used as a DCD screening instrument; the male cut off is <47 and the female cut off score is <53 (Hay, Hawes & Faught, 2004). The sensitivity is 91% and specificity is 87% for detecting impairment in motor proficiency (Hay, 1992).

It was therefore considered a robust tool to measure perceptions in this study and the strong test–retest reliability made it a good choice to measure any change in perceptions over time.

Table 5.7 Internal consistencies for CSAPPA

Total score	α = 0.92
Adequacy	α = 0.87
Predilection to participate	α = 0.87
Enjoyment	α = 0.89

(Cairney, Missiuna et al., 2008)

5.11 Data Analysis

5.11.1 Issue surrounding conventional statistical analysis

In order to answer research question 5.1.1 'What are the characteristics of children with different severities of DCD compared to children without DCD?' it was necessary to compare the children. One way of approaching this was through statistical analysis. However, there are a number of issues surrounding conventional statistical analysis in DCD research.

Conventionally researchers have used group means and inferential statistics to help draw conclusions about the nature of DCD. However, this may be problematic in three ways:

1. Rigorous findings are not only dependent upon good study design but also on recruiting sufficient sample size, to allow adequate power for inferential statistical analysis. Yet, recruitment of sufficient numbers of children who meet the criteria for DCD is a challenge in any study. Recent published studies on DCD were consulted to review sample size

and power, where they were quoted. Sample size typically ranged from 10-20 per group (see Table 5.10).

2. There is currently some contention about the meaningful use and presentation of inferential statistics. For example, what constitutes statistically significant results and which statistical theoretical approach to use (Trafimow & Marks, 2015; Perezgonzalez, 2015). However, with careful analysis of the data, using first descriptive statistics and then a clear choice of theoretical approach for hypothesis testing, inferential statistics can play a useful part (Perezgonzalez, 2015).
3. Group comparison between TDC and DCD children has been criticized, as described in chapter four. Even if statistically different, it does nothing to explain anything about heterogeneous individuals or underlying causes (King et al., 2011). Furthermore, the information gained about any individual differences is lost (Cantin et al., 2014). This suggests that alternative methods should augment or replace this approach.

An explanation of how each of these challenges was approached in this study will follow.

5.11.2 Inferential statistical analysis

5.11.2.1 Null hypothesis significance testing:

A further consideration in any study intending to use inferential statistics is the recent debate about the contentious use of p values to indicate statistical significance. Trafimow & Marks banned their use in 2015 in the editorial of Basic and Applied Social Psychology, arguing for stronger descriptive statistics and greater consideration of effect size to determine whether or not test results have any significance that might relate to real world differences (see Trafimow & Marks, 2015 for a discussion). However, Perezgonzalez (2015) suggested that the misinterpretation of statistical results has both statistical and theoretical sources and blamed a conceptual mix up between Fisher's and Neyman-Pearson's approaches to Null Hypothesis significant testing (NHST). Fisher's approach tests data on a null hypothesis and uses level of significance to

ascertain the probability of the data under the null hypothesis and seeks significant results.

By contrast, Neyman-Pearson's seeks to make a decision by testing data on a main hypothesis and decides in favour of an alternative hypothesis according to a cut-off calculated a priori, based on sample size (N), Type I error probability (α), effect size (MES) and power (1- β), the latter two are provided by the main hypothesis (Perezgonzalez, p1, 2015). This study adopted the Neyman-Pearson's approach and so sample size and power were determined a priori.

5.11.2.2 Determining the statistical power required:

The ability of a test to find a significant effect is known as the statistical power (Field, 2018). This is the probability that a given test will find an effect assuming that one exists in the population. This is the opposite of the probability that a given test will not find an effect assuming that one exists in the population (the β level), i.e. the Type II error rate. Therefore, the power of a test can be expressed as 1- β. Given that Cohen (1992) recommends that a 0.2 probability of failing to detect a genuine effect, the corresponding level of power would be 1- 0.2, or 0.8. We therefore typically aim to achieve a power of 0.8, or have an 80% chance of detecting an effect if one genuinely exists.

There are a number of steps that are required in order to determine power and sample size and they are inter related, but before describing them it will be useful to examine the effect and sample sizes that other published research on DCD has used. Green (2007) adopted this approach and identified four studies from 1990 to 2001 that had identified effect size. Since then others have adopted this approach (see Table 5.8).

Table 5.8 Comparison of DCD studies and effect sizes

Study	Measure	Effect size	Sample size
Humphries et al. 1990	BOTMP	0.86	20
Shoemaker et al. 1994	TOMI	0.86	35
Miller et al. 2001	BOTMP	0.35	20
Polatajko et al. 2001	MABC	0.55	14
Ferguson et al. 2013	MABC2	0.5	17 per group
Wilson et al. 2016	MABC2	0.7	10 per group

Field (2018) advocates determining the power for a statistical test a priori and involves considering

- How big the effect is (bigger effects are easier to detect)
- The sample size – If test statistics can be considered a signal-to–noise ratio, the bigger the sample (and better approximation of the population) the less 'noise' and easier to find the 'signal'
- (α) the probability of a type I error (mistakenly believing there is a significant effect when none exits), usually set at 0.05.
- (β) the probability of a type II error (mistakenly believing there is no effect when one actually exits), usually set at 0.2

The power of a test is expressed as 1- β, usually 0.8 in social sciences.

Given that there is an inverse relationship between α and β, a trade off can be made to attempt to minimize the probability of making both types of errors. Hinkle et al. (1994) suggest that by minimizing β the power is maximized, but while α is under the direct control of the researcher β is not. It is custom and

practice in social sciences to set α level of significance at 0.05. This is because in the social sciences the consequences of a type I error is deemed more serious than a type II error. The converse is true in medical research, where the α level is set very low (0.001) due to potential harm to patients if a treatment is said to be more effective than a standard treatment when it is not. β to α ratio of 4:1 is therefore suggested in Social Science research (Hinkle, Wiersma & Jurs, 1994). Thus power (1- β) is 1-4(0.05) = 0.8, which leads us to now consider effect size.

5.11.2.3 Effect size:

Cohen defined the effect size as 'the degree to which a phenomenon exits' (Hinkle et al., 1994, p294) and so the larger the effect the easier it is to detect. However, the likely effect size in a population can be estimated by using data from past research and this can be used to inform the size of sample required for the study (Field, 2018). See Table 5.10 for DCD research that informed this study.

Effect size measures either the sizes of associations or the sizes of differences between the outcomes or groups under investigation (Walker, 2008). The most common measures of effect size are the correlation and regression coefficients r or R. As correlations cover the whole range of relationship strengths from (-1 through 0 to 1) it states how large the relationships are. Yet, importantly is independent of how many participants are tested. Cohen (1988) provided rule of thumb for interpreting effect sizes and these are generally accepted in research (Walker, 2008). A small effect would be Cohen's d of 0.2, a medium effect would be 0.5, a large effect size would be 0.8 and very large would be 1.5. However, effect sizes can help determine sample size a priori, for example Dunlop & Myers (1997) suggest approximate sample sizes for each effect size (see Table 5.9).

Table 5.9 Effect size and corresponding sample size

	Small	Medium	Large
Cohen's d	0.2	0.5	0.8
Sample size	402	66	28
Correlation	0.1	0.3	0.5
Sample size	800	88	32
2x2 table	0.1	0.3	0.5
Sample size	800	88	32

Thus by using α of 0.05 and power of 0.8 a minimum sample of 32 is required for any correlation study and a sample of 28 is required to demonstrate large effect.

In this study a sample of 34 children was recruited. Allowing for 10% attrition over the course of the study left 29 children and therefore permitted statistical analysis.

However, for a statistical comparison of the groups (Red, Amber & Green), because smaller numbers of children were available per group, the effect size had to be increased to 1.5 in order to maintain a power of 0.8.

Hinckle et al. (p 637,1994) provide tables to determine sample size for known power using 2 tailed interval data (see Table 5.10).

Table 5.10 Effect size, power and sample size for two-tailed hypothesis

Effect size	d value	Power	2 tailed	Sample size
Medium	0.5	0.8	2 tailed	34
Large	0.8	0.8	2 tailed	15
Very large	1.5	0.8	2 tailed	8

By applying this to the children recruited to this study it was possible to ascertain whether it was viable to use inferential statistics in the analysis of the group data.

5.11.2.4 Determining sample size

It is possible to calculate the sample size required to detect an effect if we know the power, the effect size and the chosen values of α and 1- β (Field, 2018).

Thus, by setting α at 0.05 and power of 0.8 it was possible to use inferential statistics to examine medium to large effect sizes with the sample size recruited in this study (see Table 5.10). However, this was undertaken after first examining the data using descriptive statistics. Gorard (2003) cautions that the standard error is larger with sample size less than 20. Moreover, precedent exists for small sample size in DCD, a recently published study on DCD by Wilson et al. (2016) used power of 0.8 and large effect sizes r= 0.70 (d=1.5), which determined they could use a sample of minimum of 10 per group. Field (2018) suggests that a power of 0.8 is sufficient to detect any effects that exist.

Therefore, for this study, assuming large effect sizes r=0.70 (d=1.5) and α= 0.05, a sample of minimum 8 per group would be sufficient for a power of 0.80 for a two tailed test, see Table 5.10 (Hinckle et al., 1994, p637).

Table 5.11 Sample size recruited to the prospective study

Data Time point	Sample size Recruited
T1	34
T2	31
T3	29

Change over time in this study posed more of a challenge because of small sample sizes due to attrition (see Table 5.11). However, if a power of 0.75 and large effect size of d=1.5 is accepted, a minimum sample of 9 per group would detect differences between 3 levels of measurement (Hinckle et al., 1994, p 638). Thus, it was possible to use inferential statistics to compare groups within the sample, but the power of the results was reduced from 0.8 to 0.75 to accommodate small sample sizes. However, the results would still have to be interpreted with caution.

Nonetheless, as previously discussed, group comparison can only give broad notions about group mean behaviour over time and does not provide us with detail about intra-individual motor change. Other researchers have highlighted this in the field of DCD and King and colleagues (2011) provide a useful critique of some of the previously adopted methods, please refer to the previous chapter for a discussion.

Summary

By exploring the sample size, power and choice of statistical analysis in peer reviewed papers published on DCD, it helped to distinguish whether using inferential statistical methods would be viable for this study and what effect size to expect. Adopting a Neyman-Pearson's approach to hypothesis testing, determined the power and sample size a priori, along with setting alpha at 0.05 and testing for a large effect made the statistical analysis more robust and transparent.

This influenced the choice of method of analysis for this study and it was concluded that the sample size recruited would be adequate to undertake statistical analysis, providing the effect size and power were quoted. The methods are detailed in table 5.12

Table 5.12 Investigations and main analysis for this study

1. Sample characteristics which may influence analysis and outcome (e.g. Age, gender, IQ, SES, AC)	Frequency distribution, Komomgorov – Smirnov, ANOVA of children with and without movement disorder
2. Sample characteristics of RED, AMBER & GREEN groups at baseline	Descriptive comparison based on MABC2 total score and comparison with previous studies
3. Motor change over time and group comparison	Individual case series total score of MABC2 ≥ 10 point change, repeated measures ANOVA
4. CSAPPA change over time and group comparison	Total score of CSAPPA, Repeated measures ANOVA
5. Contribution of additional factors that could influence motor development (e.g. car ownership, parent attitude, SES)	Post hoc analysis Case study contextual data Supported by case interviews
6. Impact of Associated Characteristics of children on their acquisition of motor skills	Correlation analysis
7. Impact of Associated Characteristics of children on their participation in extra curricular physical activity	Correlation analysis Supported by case interviews

Another consideration is that ANOVA assumes equal group size and equal homogeneity of variance, which may not be the case with the data. Although these approaches have been frequently adopted in DCD research, they do not capture individual differences or individual change over time.

In order to address this a case study approach was also adopted to highlight individual cases and examine them over time.

5.12 Case study

The extant literature agrees that DCD is complex and frequently co-occurs with other developmental conditions such as ASD or ADHD, but how each family responds to these will differ. Each family is unique and will have differing attitudes and will place different values on physical activity. The families will also have different resources available to them. Furthermore, development of a child's motor proficiency depends upon numerous factors such as perceived self- competency (Skinner & Piek, 2001), motivation, interest and enjoyment (Cairney et al., 2007), the affordances endowed by a child's physique (Sugden & Wade, 2013, p.65), prior experience and the resources available (DSM5, APA, 2013). One measurement tool cannot therefore capture all of these factors. Moreover, as the change in motor proficiency over time in this study marked developmental change and we have already heard that child development is a dynamic interaction between a child and his or her environment, it was important to acknowledge this interaction by incorporating an ecological design through Bronfenbrenner's bioecological framework.

Case study methodology was therefore best placed to facilitate investigation between some of these factors and allow integration of the analysis of the layers of data of how and why change over time may have occurred. Yin (1984) described case study as an embedded design that is multiple levels of analysis in one study. The multiple levels in this study comprised questionnaires on parents' attitude and parent resources, child self-efficacy questionnaires, contextual data, child-standardized measures of IQ, direct

observations and child interview, as well as objective measurements of change in motor performance ability over time. These represented the micro- and meso- system environments that each child encountered and Bronfenbrenner's bio ecological model provided a framework for analysis of these data.

Thus by combining multiple data collection methods in this study it was possible to examine the quantitative data for any relationships and use the qualitative data to understand the context for rationale or theory underlying those relationships. It is this ability to probe deeply into the peoples thinking, beliefs and feelings about their actions that allows us to understand what happens and why it happens (Arksey & Knight, 1999). Interview is an effective way of collecting this data and the selection of cases is crucial, as the population from which they are chosen defines the set of entities and the limits for generalization (Eisenhardt, 1989).

The population in this study was children attending mainstream school and, so importantly, the cases were selected from a school population rather than a clinical population in order to capture some undiagnosed children with DCD as it was hypothesized that they may have developed helpful strategies to remain 'under the radar' of services. The child interview data supplemented the detailed baseline profile of characteristics and measurement of change for specific cases. Silverman (1997) suggested that the strength of qualitative research lies in its flexibility and ability to reveal the unexpected, if the researcher is open to new data. Thus by interviewing the children in school and observing their interactions with staff, peers and the interviewer, a more detailed picture of each case was constructed. Furthermore, an additional advantage of adopting a case study method is that it allows this flexible and opportunistic data collection to examine evidence for the 'why' behind relationships and this helps build internal validity in the study (Eisenhardt, 1989). Case study method was therefore chosen to strengthen the internal validity.

5.12.1.Use of theory and previous research to guide data collection

As there are no clear pre-established set of outcomes about the nature and progression of different profiles of DCD, an exploratory approach to case study was used in this study. Stake suggested that a number of cases could be studied jointly to inquire into a condition, population or phenomenon; he called this a collective case study and classified it as an instrumental study extended to several cases (Stake, 1994). Each case in this study was specifically chosen in order to advance the understanding of the characteristics and progression of DCD over time. The cases were chosen using the framework described in Fig. 5.3 and their ecological context was also investigated to help conceptual and theoretical development about how different influences effected progression for children with DCD and without DCD and whether or not associated conditions impacted outcomes in their experiences of participation in extra curricular PA.

Yin (2009) advised the development of a theory prior to collection of any case study data to provide guidance about what data to collect and strategies for its analysis. The theory can be as simple as a hypothetical story predicting why events, thoughts and behaviours occur or consulting existing work, which may already provide a good theoretical framework. In this study existing work guided the pre-specified criteria of self-perception (Cairney et al. 2005; Hay, 1992; Skinner & Piek, 2001), friends (Poulsen et al, 2008), family support and resources (Welk, Wood & Morss, 2003; Zecevic et al., 2010), type of associated characteristics (Green et al., 2006; Missiuna et al., 2014;) and severity of motor impairment (Poulsen, Ziviani & Cuskelly, 2007) to explore in relation to the experience of children's participation in PA.

The benefits of using a theory are a stronger design and better ability to interpret the eventual data (Yin, 2009). Yin (2009) also acknowledged that for some topics there may be little existing available literature or knowledge providing a conceptual framework, as is the case for an exploratory study, and this was the case for the progression of children with the different severities of

DCD. In this case Yin (2009) advocated the use of a wider range of theories that may be relevant to the study, such as theories of cognitive or social development or learning and social interaction, self efficacy and play theories, as this is the level at which generalization of the case study results occur. This study drew on theories of motor development; dynamic ecological explanations for participation and child development and Bronfenbrenner's bioecological model provided the framework with which to integrate the data.

5.12.2 Framework for determining cases:

Please refer to Fig.5.2 for the procedure for identifying and selecting cases to ensure that the heterogeneity of the school population sample was represented.

The table 5.13 shows the rationale for selecting the cases of children who represented the full range of profile characteristics in order to interview and examine the experiences from each category. This sampling method was theoretical rather than statistical and allowed the possibility of comparing polar types (Eisenhardt, 1989). For example, comparing a child with typical motor development and associated characteristics with a child with DCD and associated characteristics in order to extend or replicate any emerging theory or hypothesis.

Table 5.13 Rationale for selecting cases for interview and number of children interviewed in each category

Groups	Plus Associated Characteristics	Without Associated Characteristics
RED DCD≤5th MABC2	N=1	N=1
AMBER 6-16th MABC2	N=1	N=2
GREEN ≥25th MABC2	N=2	N=3

In order to answer the research question 5.1.3 ‘How do the characteristics and stability or change in motor ability and self perceptions impact on experiences of participation in physical activity from the child’s perspective?’ cases had to be selected from each of the groups that had particular characteristics and had either stable or changing profiles. A further caveat was whether the child participated in extra curricular activity or not.

As the design incorporated Morse’s priority sequence model of Quant-Qual sequential mixed methods (1991), the children’s characteristics and profiles were determined from analysis of the quantitative data from the MABC2, the DCDQ (07) and the CSAPPA and then specific children who demonstrated particular profiles were selected. Thus selections of children from all motor groups were chosen (see Table 5.14) and this is illustrated with an example of the profiles chosen for the Red group (severe DCD) that included:

- A child with severe DCD plus associated characteristics who did not participate in extra curricular PA (the norm for the Red group)
- A child with severe DCD plus associated characteristics who did participate in extra curricular PA (exception for the Red group)
- A child with severe DCD only who did participate in extra curricular PA (exception for the Red group).

This method also permitted cross case analysis for both similar or opposite cases, thereby extending the type of analysis possible.

The subjective account of how a child makes sense of their situation can illuminate reasons for their participation with people, situations, and tasks and determine how they progress. This was elicited by individual interview with the researcher and the procedure outlined in Table 5.14 informed the selection of children for the interviews.

Table 5.14 Case selection criteria for case study methodology

A child in Red Group ≤ 5th percentile MABC2		**A child in Amber Group 6-16th percentile MABC2**		**A child in Green Group ≥25th percentile MABC2**	
With AC	No AC	With AC	No AC	With AC	No AC
Who Participates in PA	Who Participates in PA	Who Participates in PA	Who Participates in PA	Who Participates in PA	Who Participates in PA
Who does not participate in PA	Who does not participate in PA	Who does not participate in PA	Who does not participate in PA	Who does not participate in PA	Who does not participate in PA

5.12.3 Rationale for the interview schedule:

Previous research in the field of DCD in children has highlighted the potential impact of DCD on numerous activities in daily life (Missiuna, Moll, Law, King & King, 2006; Missiuna, Moll, King, King & Law, 2007) and it was important to capture this information.

The ICF (WHO, 2001) provides a useful framework for examining participation for children, as it examines participation under categories of work, leisure and activities of daily living, and so provided logical areas to investigate in this study. Moreover, the ICF acknowledges the person and environment as dynamic and interactive dimensions in an ecological approach similar to that of Bronfenbrenner (Stewart & Rosenbaum, 2003) and so is compatible with the study design. Therefore, arts-based semi-structured interviews focusing on participation in self-care, work and leisure, and in particular, participation in physical activity were therefore chosen for this study. These areas were guided by categories from the ICF and from previous research in DCD (Missiuna, et al., 2006; Missiuna, et al., 2007). This resulted in a series of photographs depicting

activities for each category to act as a visual prompt if required to elicit responses. Furthermore, the social and cultural environments are also important as a child's participation in activities is also affected by attitudes, values and beliefs (Law et al., 1999) and therefore data on child and parent attitude supplemented the interviews. Observations on the wider cultural environment, such as media portrayal of gender roles and curricular time allocated to PA also augmented the data.

Please refer to the interview schedule in appendix 7

In addition to the areas described in the ICF the schedule, grand tour questions were asked aiming for insights from the children about difficulties and successful participation.

Summary

Qualitative research was used to enable the child to describe his or her context in detail to illuminate underlying processes, motivations and possible explanations for phenomena or set of behaviours, which may well be context dependent. Group means and statistical analysis could only reveal general trends and so more detailed analysis, with a case study approach augmented with interviews and examined particular cases within their context. As this study examined the progression of motor profiles of children with DCD it was crucial to include rich description of their everyday context and their subjective experiences in order to determine any potential causal explanations for patterns of change over two academic years and their outcomes. The questions most appropriate for case study research are concerned with how things happen and why (Anderson, 1998; Bryman, 2010). The research question was concerned with how the motor profiles of children with different severities of DCD change over time and the factors associated with why the particular changes occur and the impact they have on participation in physical activity, case study was therefore an appropriate framework.

5.13 Reflections on the unique features of the study

In summary the DCD literature has identified potential sources of heterogeneity, which may be problematic for research, and this design aimed to account for, and describe them. Data were documented at the baseline for each child and included:

- the severity of motor impairment (whether ≤ 5th percentile on MABC2 or 6-16th percentile)
- the presence or absence of co-occurring associated characteristics
- the level of IQ
- the age and sex
- the parent's opinion on the impact of motor impairment on daily life.

However, there is also complexity surrounding the identification of children with DCD and it is, to a certain extent, dependent upon the measures employed, their specificity and sensitivity and the cut-off scores chosen. There is also the potential for discrepancy between the measures and between the various people who associate with the child. Identification of psychometrically sound measures is essential to try and ameliorate this, but it is also apparent that consensus guidelines are very important. Both these approaches have been adopted in this study.

An important part of the study was to examine any change in motor performance of the children with DCD over time to help better understand their development. Development is a complex process involving dynamic interaction between the child and his or her environment. However, for any causal inferences to be made about atypical development a study must include typically developing peers for comparison. This study included peers who had been identified without movement difficulties, yet the screening process also identified that some of them had associated characteristics. This highlighted the importance of identifying the profile of all the study participants at baseline before tracking their progression over time.

However, the measurement of change in motor performance is not itself a straightforward process, as there is no consensus about how meaningful change should be identified and different researchers have employed different criteria. This study adopted three approaches: the MABC2 traffic light system, motor group change and MABC2 total score ≥10 points (larger than the standard error measurement) called the smallest detectable change (SDC) (Holm et al, 2013).

Furthermore, the importance of environmental context in child development includes family context and the resources available to the child, as these have been found to impact progress. Therefore, the family context of each child was also documented and included:

- the parents employment status
- family car ownership
- number of school aged children in the family
- parents health status
- family history of developmental disorder

Additionally, literature has highlighted that family attitudes can have a role to play in participation rates in physical activity and that movement experience impacts upon motor performance. For this reason the parents were asked about:

- how important they ranked participation in physical activity
- how frequently they engaged in physical activity
- how severe the impact of their child's motor impairment impacted family life

Moreover, self-efficacy has been discussed in DCD literature and also been identified as a potential factor in child participation rates in physical activity. Children in this study were therefore questioned about their self –efficacy and enjoyment of participating in physical activity.

Statistical analysis has also come under scrutiny in DCD research and is particularly pertinent for such a heterogeneous population, as homogeneity of variance is easily violated rendering tests such as ANOVA less reliable. The utility of general linear models (GLM) and comparing group means are also questioned because small sample and unequal sample sizes are all problematic for these tests, yet much more likely in DCD research. In addition, the intra-group differences in populations with DCD may be more important than the inter-group differences with typically developing children. Individual case series approach to motor change permits examination of intra-group variability, which may be an important indicator in future research in DCD. A more flexible analysis of the data considering different aspects, such as the real world impact of impaired motor performance, participation in physical activity and daily life has been added to supplement statistical analysis in this study. Furthermore, the child's own perspective has been sought in interviews of selected cases of children with particular profiles in order to more fully understand the impact of different profiles on participation. Adopting an ecological approach facilitated a more comprehensive analysis of the nature of DCD, its change over time and the perceived impact on participation in physical activity.

CHAPTER 6 RESULTS

6.1 Findings from Research Question: How do the profiles of children with DCD change over time?

6.1.1 What are the characteristics of children with different severities of DCD compared to children without DCD? These will include their:

- Motor characteristics
- Associated characteristics
- IQ
- Ability to take part in everyday activities
- Socio-economic context and family context
- Self- perception of their adequacy, enjoyment and predilection to participate in physical activity

6.1.2.1 How stable are the motor characteristics or do they change over time?

6.1.2.2 How consistent are their self-perceptions of their adequacy, enjoyment and predilection to participate in physical activity or do they change over time?

6.1.3 How do the characteristics and stability or change in motor ability and self-perception impact experiences of participation in physical activity from the child's perspective?

The following sections describe the participants who took part in the study and how they were identified. The results are then presented in three parts.

Part I describes the fine-grained detail of the characteristics of children with and without DCD at the baseline of the study. This included any known co-occurring conditions or characteristics associated with co-occurring conditions, an

estimation of their IQ (including verbal and non-verbal components), the extent to which their parents considered their motor difficulty impacted daily life, demographic characteristics, and the child's perception of their motor abilities. Since the identification of children with DCD is complex and can be problematic, an analysis of the consensus between the different sources of identification of the children with motor impairment is also examined. Analysis of the characteristics that brought the children with movement problems to the attention of teachers can help us understand part of the complexity of identifying DCD. So there is a description of the comparison of the characteristics of the children who were classified by those with motor impairment (i.e. ≤ 16th percentile) and without motor impairment (>25th percentile chosen to clearly differentiate the typical children) on MABC2 respectively and any differences are presented. The children were then further classified according to the severity of motor performance ability impairment into Red (severe ≤5th percentile), Amber (moderate 6-16th percentile) and Green (typical motor ability ≥25th percentile) groups for more fine grained analysis in order to answer research question 6.1.1. Any difference between the groups at baseline is described and presented.

Part II explores how we look at change in motor ability over time and change in self-perceptions of enjoyment, adequacy and predilection to participate in physical activity over time. The three groups are investigated for any differences in stability or change in their actual motor performance (tested by MABC2) and simultaneously investigated for stability or change in their perceptions of motor performance (tested by CSAPPA) over 3 data points. These relate to findings from research questions 6.1.2.1 and 6.1.2.2 respectively. The progress of children with different severities of DCD is described and compared to typically developing children.

Part III explores the impact of their characteristics and self-perceptions on the experiences of the children with DCD to participate in physical activity. Selected case studies are presented to illustrate the progression of some

children from each group and explore some of their contextual data in relation to Bronfenbrenner's Bio ecological model. This will help us understand the interactions of the child with DCD and their particular characteristics with their specific family and school environments. These are enhanced by analysis of some interview data from the children selected for case studies in order to answer research question 6.1.3 and provide insight into children's experiences of participating in PA from their perspective.

6.2 Part I: Sample Description

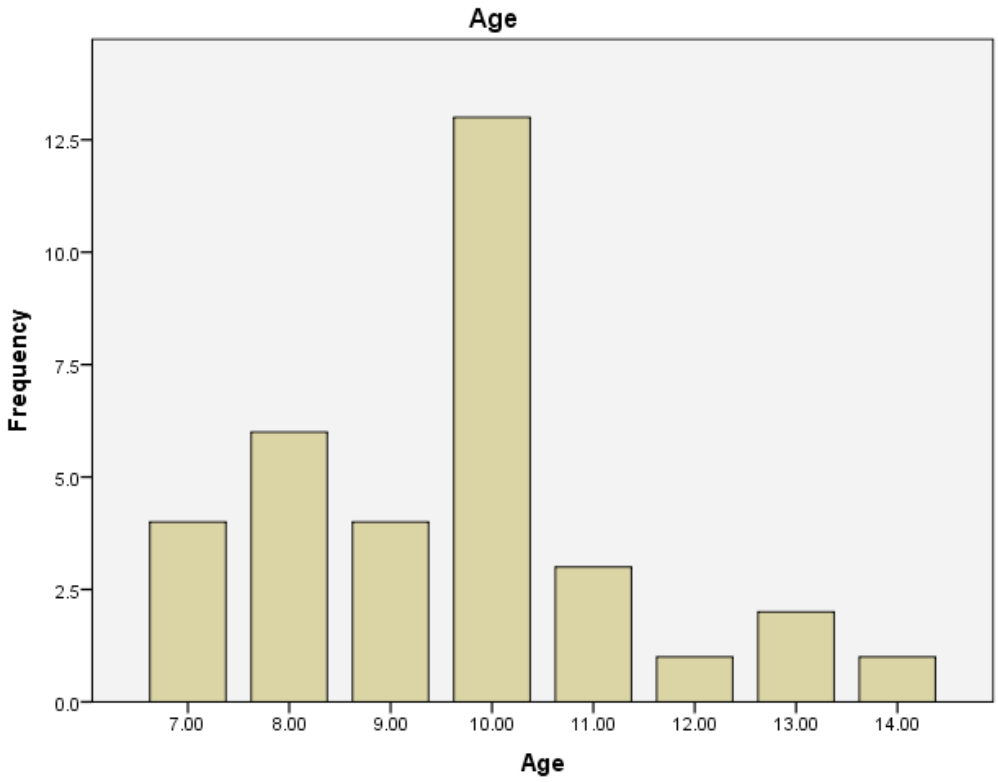
The sample was recruited from school populations (rather than clinic populations) to eliminate potential referral bias and to identify any undiagnosed children with DCD. The first section describes the entire sample characteristics, which is followed by a section detailing the comparison of children with and without motor impairment and their respective characteristics. Finally, detailed analyses of the characteristics of the Red (≤5th percentile), Amber (6-16th percentile) and Green (≥25th percentile) groups (classified by category of motor performance ability of total score on MABC2) are compared for any differences.

6.2.1 Sample characteristics

Data were collected over 2 academic years from 34 children in mainstream schools whose parents had given their consent. Children were recruited from primary and secondary schools, however, the majority of children (85%) attended one primary school with an ASD unit attached. This school was situated in an area of deprivation. The total sample consisted of 29 males and 5 females and ages ranging from 7-14 years (90- 169 months), mean age 120.8 months and standard deviation of 19.8. At the start of the study 14 children were aged 7-9 (41%), 16 children (47%) were aged 10 or 11 years and 4 were 12-14 years (12%).

It was harder to recruit children from secondary schools and more difficult to schedule testing in their timetable, which accounts for the majority of the sample being recruited from primary school.

Figure 6-1 Distribution of ages of the sample at baseline



The preponderance of 10 year olds in the sample may have arisen from the teacher awareness of imminent transition to secondary school and the importance of needs assessment.

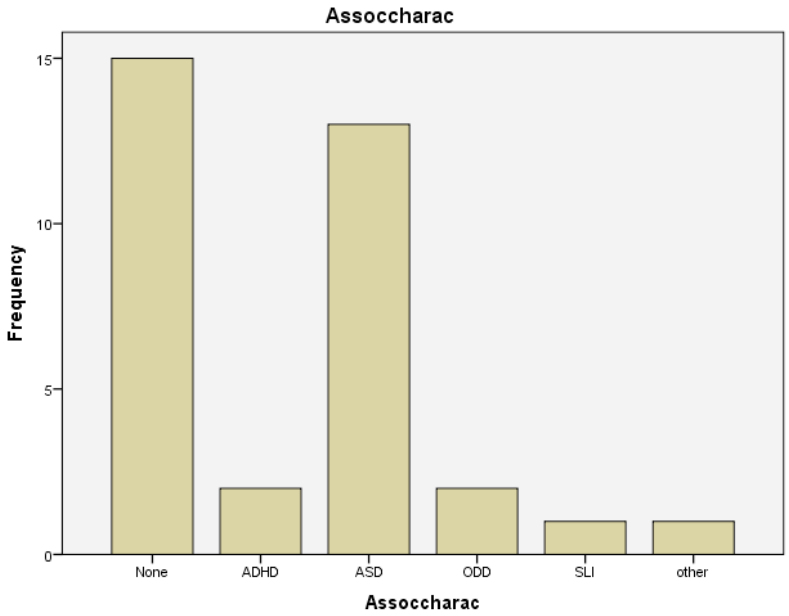
Table 6.1 Characteristics of total sample

	Total N=34	ASD N=12	SLI N=1	ADHD N= 10	ODD N=2
Male	29	12	1	10	2
Female	5	0	0	0	0
Primary school	29	11	1	10	2
Secondary school	5	1	0	0	0

The children were screened for associated characteristics of additional developmental disorders, such as attention difficulties, language and

communication difficulties. One child (2.9%) screened positive for characteristics of specific language impairment (SLI) and 12 (35.3%) of the children either already had a diagnosis of ASD or screened positive for characteristics of ASD. In addition 10 children (29.4%) screened positive for ADHD, however 9 of these children additionally screened positive for ASD. That is 9 children (26.5%) had characteristics of both ASD and ADHD. One child had a hearing impairment and wore one hearing aid.

Figure 6-2 Distribution of associated characteristics



The sample consisted mainly of boys (85.3%) at a ratio of almost 6:1 boys: girls. This may have reflected a bias of teachers identifying movement difficulties more readily in boys, or may just be reflective of the fact that 35% of this sample had ASD, which is diagnosed 4 times more frequently in boys (DSM5, p57, APA, 2013).

However, most studies of DCD describe ratios of between 2:1 to 7:1 boys to girls (DSM5, APA 2013). Furthermore, 85% of the sample was drawn from a primary school with an ASD unit attached, which naturally led to a higher

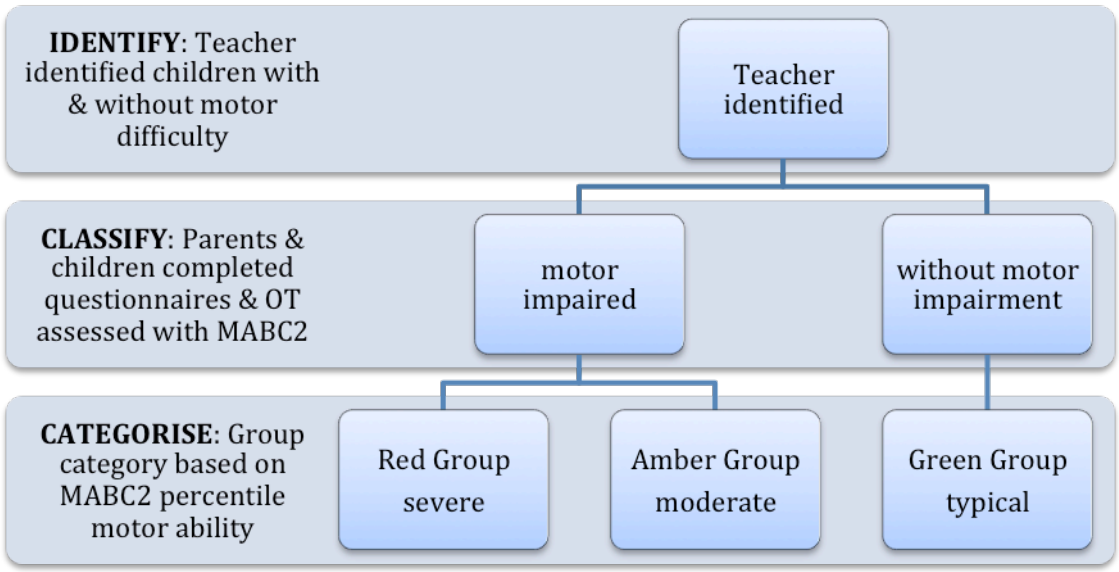
concentration of children with ASD and their siblings attending the school. The usual prevalence of ASD in UK schools is 1-2% (Baron-Cohen et al., 2009).

6.2.2 Identification of the sample

The way the sample was identified and classified is illustrated in figure 6.3

Teachers used their professional judgment to identify children without motor difficulties or intellectual impairment and identify those with motor difficulties. This is often how children with DCD are first referred to services and it is important to ascertain how effective teachers are at identifying potential motor problems. Therefore, a comparison of results from the different tools used to identify the children with motor difficulties is also reported.

Figure 6-3 Sample identification and classification



The children were screened using parent and child questionnaires and finally assessed individually by a qualified OT with a standardized, culturally appropriate movement assessment to identify the children who scored in the lowest 16th percentile, as recommended by the EACD guidelines (Blank et al.,

2012). Any child who scored at or below the 16th percentile is described as 'at risk' of motor difficulties and those who score at or below the 5th percentile are described as having 'significant' movement difficulties (Henderson, Sugden & Barnett, 2007).

The flow chart (Fig. 5.2) in the methodology details the procedure; the number of children identified at each stage and the numbers classified in each group at data point 1 (T1) or the baseline of the study.

6.2.3 The context and characteristics of the sample at baseline

The context and characteristics of the sample in this study at baseline are important because they are a little unusual. Thirty-five percent of the sample had ASD and the IQ range was large, from 55 (moderated learning difficulties) to 131 (above average). In addition 41% of the children had a family history of developmental disorder and at least a third of the children received free school meals, indicating a level of financial hardship for the families.

A summary is presented in table 6.3 about the characteristics of the children in the study sample. However, the ecological context of the neighbourhood, and the educational context of the school were also considered within Bronfenbrenner's framework.

6.2.3.1 Macrosystem level: the neighbourhood borough

The geographical area in the study had an average level of unemployment and an average utilisation of outdoor space for exercise, when compared to England as a whole. However, the number of children in low income families was higher than average (19.6 compared to 17.0 for England) and the income deprivation indices based on 2015 figures was higher than average (20.1 compare to 14.6 for England) (Marmot indicators, Public Health England, 2019).

6.2.3.2 Exosystem level: educational context of the borough

There was a higher incidence of learning difficulty and moderate learning difficulty when compare to the national average (PHE, 2019). There was also

twice the national average of free school meals in the area and a higher rate of children with special educational needs.

Table 6.2 Comparison of sample neighbourhood

	Neighbourhood	**England**
Moderate learning difficulties	39.3 per 1000	28.9 per 1000
Autism	13.3 per 1000	13.7 per 1000
Leaning difficulty	44.1 per 1000	33.9 per 1000
Free school meals	26%	13.5%
Special Educational Needs at primary school	16.3%	13.8%

6.2.3.3 The mesosystem level: the school

The primary school was an average size (234 pupils attended in 2014), mainly white British pupils, but well above average proportion of pupils were supported at school action plus or had a statement of special educational needs. The proportion of pupils eligible for support through pupil premium funding was almost three times the national average in 2014, with 67.5% of pupils eligible for free school meals. There were two specially resourced bases, one for each key stage, supporting up to 14 pupils with autism from across the borough.

The Ofsted report 2014 rated the school 'Good' and commented, "This is a happy and caring school. It provides a calm and nurturing environment, particularly for those pupils who attended the specially resourced bases. As a result, pupils achieve well given their differing abilities." (OFSTED, 2014).

6.2.3.4 The microsystem level: the children and families

After considering all the information the children were initially categorized and divided into:

i) Those with movement impairment substantially below that expected for their age and opportunity DCD (≤16th percentile of MABC2) and

ii) Those with no movement impairment potentially typically developing (≥25th percentile of MABC2, pTDC).

This was to determine any differences between the motor impaired children and those without a motor impairment at baseline and may also allow some insight into the characteristics that alert teachers to identify children with DCD.

Table 6.3 Characteristics of the study sample

	Entire sample n=34	**Mean (sd)**
Age in months: range	Range 90-169	120.8 (19.8)
IQ: range	Range 55-131	95.2 (20.5)
Number with ASD	12	
Number with ADHD	9	
Number with ODD	2	
Number with other	2	
SES free school meals	11 (7 did not respond)	
Family history of developmental disorder	14 (41.2%) known but others did not respond	

6.3 Comparison of the characteristics of motor impaired and non-impaired children

The gender distribution was roughly equivalent between the motor impaired and non-motor impaired groups, although the mean age was slightly older for the non-impaired group. The children in the motor impaired group had a higher prevalence of associated characteristics and both their general IQ and verbal IQ scores were lower than the non-motor impaired group. However, the number of children with a significant difference between their verbal and non-verbal IQ

scores was higher in the non-motor impaired group. A large discrepancy here is considered abnormal in the general population (Kaufman & Kaufman, 2004, p34) and this result may indicate that the sample of non-motor impaired children (TDC*) may not be typically developing in domains other than motor.

Table 6.4 Comparison of movement impaired and non-movement impaired groups at baseline

	DCD (movement impaired) n=17	**TDC* (non-impaired movement) n=17**
Gender	Male n=14 Female n=3	Male n=15 Female n=2
Age	Mean = 117.6 (sd 18.8) Range=90-161	Mean = 124.1 (Sd 20.9) Range=94-168
MABC2 TI score	Mean = 45.7 (sd 17.2) Range =16-67	Mean = 77.5 (sd 7.7) Range 69-94
KBIT2 General IQ	Mean = 83.8 (sd 19.5) Range= 55-122	Mean = 106.5 (sd 14.6) Range=71-131
KBIT2 Verbal IQ	Mean = 85.7 (sd 15.5) Range= 52-122	Mean = 109.5 (sd 13.4) Range= 86-132
Difference between VIQ & NVIQ **Sig. to 0.05 or 0.01**	N=7 41.2%	N=9 64.3%
Children with Associated characteristics	Attention = 8 ODD =1 ASD=11	Attention=2 ODD =1 ASD= 2 SLI=1

Thus some differences appear between the group means for motor impaired and non-motor impaired children at the start of the study for age, IQ and

associated characteristics. These were investigated further with statistical analysis and are reported later.

A comparison of some characteristics related to performance at school was also performed between the motor impaired and the non-motor impaired groups. The results are presented in table 6.5.

Table 6.5 Comparison of school performance between the groups

	DCD (movement impaired) n=17	**TDC* (non-impaired movement) n=17**
Right handed	N= 11 (64.7%)	N= 11 (64.7%)
Poor Handwriting	N=15 (88.2%)	N=4 (23.5%)
Any SEN provision	N=13 (76.5%)	N=4 (22.2%)

However, there was equivalent distribution of right-handed children in each group in this sample, although the DCD group had a greater incidence of handwriting difficulty (82% compared to 23.5%). The DCD group also had a higher incidence of children with special educational needs (76.5% compared to 22.2%). Perhaps this was unsurprising given that the DCD group had a lower mean IQ than the non-impaired motor group (83.8 compared to 106.5). Perhaps, predictably, the DCD group had considerably more difficulties than the non motor-impaired group and it would be logical to hypothesize that they would have lower self-perception and participation in PA.

Behavioural and functional outcomes are not solely determined by biological characteristics but by the bidirectional interaction of child and the environment (Bergman, Eklund & Magnusson, 1994). Therefore, by using Bronfenbrenner's model, investigation of the microsystem i.e. the interrelations

between the developing child and the immediate settings such as the family allows another layer of analysis. So too does investigation of the interrelations of the child in the mesosystem, i.e. major settings at a particular point in life (e.g. school) and the exosystem (such as parent employment), which influence (delimit, or even determine) the child's developmental setting (Lerner, 2005). Therefore contextual data concerning each child and their family environment were analysed to help establish possible influences on the child's motor progress. A summary of the parent questionnaire is presented in table 6.5. This summary was based only on the responses that were returned. Overall response rate was 91.18% but not all were complete. Complete response rate was 76.5%.

6.3.1 The Family context:

The families with the children who had motor impairment had a higher prevalence of developmental disorder in their family, perhaps indicating a familial or genetic predisposition to neurodevelopmental disorders. However, they had a lower prevalence of some of the indicators of deprivation, such as free school meals, unemployment and no family transport. Moreover, fewer of these families had two or more children less than 18 years in the household and fewer parental disability or health problems, indicating a slightly more favourable context than the non-impaired group. Despite this group having lower levels of maternal education, they generally had a slightly more favourable context, in terms of family resources, than the non motor-impaired group. An understanding of level of a child's resources and deprivation is important because previous studies have shown that these can impact levels of participation (see King, Law et al., 2003 for a review).

Table 6.6 Summary of Parent Questionnaire based on MABC2 category at baseline

	Motor impaired (DCD) n=17	**TDC* (non-impaired movement) n=17**
1st degree relative with developmental disorder	69.2%	50%
Single parent	31.3%	35.3%
2 or more children <18 years in the family	64.3%	79.5%
Parent health problems	23.1%	55.3%
Parents not employed	14.3%	41.2%
Mother education >GCSE	66.7%	71.4%
Free school meals	33.3%	46.7%
No family car	30.8%	37.5%
Importance of PA to family >score of 2	75%	58.8%
Impact of child's motor difficulty on family > score of 2	75%	23.5%
Freq of parent PA weekly or more	66.7%	68.8%

6.3.2 The Family attitude to physical activity (PA):

Family attitude to physical activity is an important motivator for participation (NICE Public Health collaborating Centre-Physical activity, 2007). In this study the parents of children with DCD appeared to rank importance of physical activity higher than the families without motor impaired children, and participated themselves at a similar frequency to the parents of the non-impaired children. Therefore, the DCD group had fewer attitudinal barriers to participation in PA than the non-impaired group. However, unsurprisingly they ranked the impact of their child's motor impairment on family life as high. The severity of the motor impairment was considered to have the potential to impact participation in PA and was therefore also investigated and is reported later.

Summary

In terms of their family context, the children with typical motor ability appeared more disadvantaged in relation to their available resources than the children with motor impairment. This was because this group had more parents with health problems (53% compared to 23%), a greater proportion of unemployed parents (41% compared to 14%), higher proportion of families with more than 2 children under 18 years (nearly 80% compared to 64%) and more families entitled to free school meals (nearly 47% compared to 33%). Yet, both groups had similar rates of single parent households, maternal level of education and parent participation in physical activity. However, the parents of children in the motor impaired group rated importance of PA higher than the parents of children with out motor impairment (75% compared to 59%) and unsurprisingly, rated the impact of motor difficulties on family life much higher (75% compared to 23%). An additional potential barrier to participation for the families with the children with motor impairment was the higher rate of first-degree relatives with a developmental disorder (nearly 70% compared to 50%). Both these figures seem higher than expected, but majority of the sample was drawn from a school with an ASD unit attached and this may have impacted the results.

The children with typical motor ability had greater potential resource barriers to participation in extra curricular PA for and a lower ranking of importance of PA

by their parents. However, the families of children with motor impairment had identified a negative impact of their child's difficulties on family life, despite ranking the importance of PA higher. They may have more barriers to participation in extra curricular PA for their children than captured by the parent questionnaire. More information over time was required to unpick some of the complexity, particularly regarding the severity of the motor impairment and impact on participation. Motor impairment is a core feature of DCD and the identification of the disorder in this study entails fulfilling criteria of DSM 5 (APA, 2013).

As previously highlighted, researchers have found that the identification specifically of DCD can be complex and involves gathering data from different sources (Blank et al., 2012). However, not all tools identify the same children (Barnett, 2008) and not all professionals can easily identify motor performance difficulty (Harris, Zwicker & Mickelson 2015). Therefore a comparison of data collected from the different sources in this study was undertaken, in order to better understand the issues, and the findings are discussed.

6.4 Findings from comparison of identification of movement difficulty

The EACD guidelines (Blank et al., 2012) advocate the importance of using multiple sources for the identification of children with DCD, but it is unclear whether all sources are of equal merit. Therefore, a comparison of the results from each source of identification was undertaken. As a result of following the above procedure

- Teachers initially identified 18 children that they thought had movement problems and 16 that they considered to be typically developing with no intellectual impairment.
- Parents using the DCDQ (07) screening tool identified 16 children they thought had difficulty with everyday tasks, who were suspected of having DCD

- Children using the CSAPPA self-rated tool identified only 8 children with low self-efficacy, enjoyment and predilection to take part in physical activity, who scored in the suspect DCD range.

Table 6.7 Different methods to identify motor impairment

Method of identification of movement problems	Movement impaired group	Non-impaired movement group	Total	Missing data
Teacher id	N=18	N=16	34	0
Parent rated DCDQ (07)	N=16	N=15	31	3
Child rated CSAPPA	N=8	N=26	34	0
Researcher (OT) MABC2 test total score ≤ 16th	N=17	N=17	34	0

In order to avoid false positive results the cut-off score for DCDQ (07) and CSAPPA was set at ≤5th percentile, as these are both screening tools. However, the MABC2 cut off score was ≤16th percentile (at risk range) in line with the EACD guidelines (Blank et al., 2012). Previous studies have identified that children who score in the at risk range experience difficulties in participation in daily living (Wang, Tseng et al., 2009) and for this reason they have been included.

It came as a surprise to the teachers that five children they had considered not to have any movement impairment tested in the impaired range and three children they thought had impairments tested in the typical range.

6.4.1 Closer analysis of the identification and assessment of DCD at baseline

The identification and assessment of DCD is not a straightforward process and involves collecting information from a number of different sources, which may not necessarily agree and potentially identifies different children, as this small sample illustrates.

As previously mentioned the EACD guidelines (Blank et al., 2012) recommend gathering data from different sources and additional testing with an appropriate standardized motor test. Table 6.7 shows how many children were subsequently verified by MABC2 (Henderson, Sugden & Barnett, 2007).

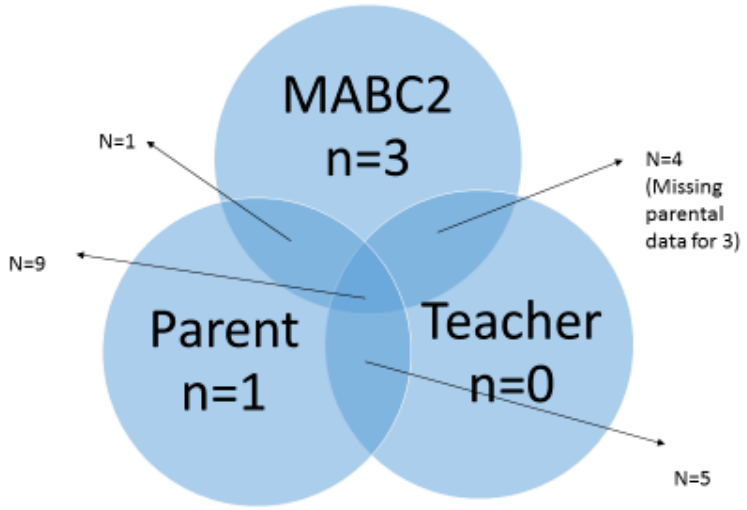


Figure 6-4 Numbers of children identified by parents, teachers & MABC2

Interestingly, parents and teachers identified 5 children suspected of movement difficulty who scored above 25th percentile on MABC2. Two of these children had a diagnosis of ASD, one had ADHD, one had ODD and one had unknown early development. However, over time it became apparent that 3 of these children did go on to demonstrate movement difficulty and associated problems. The other two also had associated characteristics, one with ASD and the other ADHD, but they consistently scored above the 16th percentile on MABC2 over

time. Conversely, one child was identified by his parent alone and confirmed by MABC2 with severe motor impairment, both at baseline and over time. Additionally, 3 children were identified by MABC2 alone, 2 of whom were girls and were not confident with motor skills but improved their MABC2 score over time and a boy who scored in the impaired range over time. He was without associated characteristics and continued to score consistently ≤16th percentile on MABC2 over time and yet, despite this, was not identified by parent or teacher as having movement difficulties.

Furthermore, two boys identified by parents, but not teachers, as having movement difficulty yet consistently scored in the typically developing range on MABC2 over time. One boy was very small for his age and the other had a diagnosis of ASD, both of which may account for the issues raised by the parents of these children.

Of the sample of 34 children, 17 were identified as having movement difficulties when tested with the MABC2. Of these only nine children, were identified by both teachers and parents as having movement difficulties, and were subsequently verified by MABC2 score (i.e. 52.9% of those correctly identified with movement difficulty) all of these children had a diagnosis of ASD, 8 of whom had additional symptoms of ADHD. This number may have been higher, as there was missing data from the parents of a further three children who all scored ≤16th percentile on MABC2.

Summary

Teachers and parents identified just over half of the children with movement difficulties from a school population, but interestingly those identified by both also had additional associated characteristics and scored in the severe range i.e. ≤5th percentile on MABC2. However, additionally both teachers and parents also identified children who did not score in the impaired range, but had additional associated characteristics. Crucially, however, parents correctly

identified two children with movement problems that their teachers had not identified, which were subsequently confirmed by the MABC2. This data illustrated the point raised about the requirement of 80% sensitivity and 90% specificity of screening instruments in population based samples (APA, 2000) and demonstrated that identification and assessment of DCD to DSM5 criteria is a complex process. The picture was further complicated by change in motor performance ability over time, as the subsequent data will show.

6.4.2 Discrepancy between tools for identification of DCD

In this study the difference in the identification of movement difficulties by different assessments is highlighted by the fact that the DCDQ (07) identified different children to the CSAPPA and their movement difficulties were not necessarily observed using the MABC2. This presents some interesting issues about DCD, adherence to DSM 5 criteria and how they relate to participation and these will be discussed later.

For example, parents using the DCDQ (07) identified five children who scored above the 16th percentile on the MABC2 (i.e. in the typically developing range). However, their parents had sufficient concerns about them to rate them low on the DCDQ (07) questionnaire, indicating functional difficulties. Therefore, the profiles of results for these children were examined in detail as they progressed over time. Four out of the five children proceeded to display difficulties in subsequent movement tests (taking them to either the ‘at risk’ or ‘severe’ motor difficulties range) and the remaining one (despite remaining in the typically developing range) had difficulties with handwriting that required remediation. This indicated that the parents had correctly identified functional difficulties, which may have been more subtle, and only been revealed on standardized tests over time.

6.4.3 Identification of DCD by use of child report (CSAPPA)

The CSAPPA also provides useful information about how each child perceives their movement ability. In this study only eight of 34 children perceived that they had difficulties and only four of these said that they did not enjoy physical activities (PA). Interestingly, two out of the four scored above the 16th percentile on the MABC2. Nevertheless, it provided some useful data about how each child perceives their enjoyment and inclination to participate in physical activities. Despite quite severe impairment in movement ability, eight out of the 10 children who scored ≤5th percentile on MABC2 stated that they enjoyed physical activity and six stated they felt reasonably competent. This indicated that they did not perceive their motor impairment to impede their participation in PA. Only four children from the entire sample stated that they did not enjoy physical activity and two of these scored above the 5th percentile on the MABC2. The CSAPPA scores appeared not to relate to the severity of their motor performance and therefore the CSAPPA, as a screening tool for DCD, did not appear helpful for identifying DCD for this sample. A more detailed analysis will follow.

Summary

It is evident that identification of children with DCD can be problematic, with different tools identifying different children. Furthermore, parents, teachers and children identified different priorities as challenging and MABC2 assessed specific motor performance ability as a snapshot at a given time. Overlap of agreement for parents, teachers and MABC2 only occurred for 53% of the sample at baseline (leaving 47% without consensus initially). Monitoring of motor performance over time was therefore important in order to verify any difficulties not recognized by other stakeholders.

The children were further categorized into groups by their movement performance ability on MABC2 to facilitate a more fine-grained analysis by motor severity of DCD.

6.5 The severity of motor impairment in DCD

The DCD group covered a wide range of movement impairment and this group also had a large number of associated characteristics. Many studies include children who score below the 5th centile, as well as those scoring between the 5th and the 15th, yet refer to the whole group as DCD (Farhat et al., 2016,). Smits-Engelsman et al. (2015) reviewed studies from 2010-2014 to determine how criterion A was operationalized. They found that 48% of the studies used 5-15th percentile cut-off and employed terms such as 'at risk', 'moderate' and 'probable DCD' and 24% of the studies used the 5th percentile cut-off and referred to 'severe DCD' or 'DCD', whilst 6.2% of the studies used other cut-off scores < 15th percentile and 22% did not report a cut-off score at all. However, not enough is known about these categories and whether they behave differently over time. Therefore, more information about the severity of movement impairment is required to help determine the nature of interaction and it's influences for children in daily life over time. Of important note in this study, is that the group with no detectable movement impairment also contained children with associated characteristics. This could impact on the study results, so these children were closely followed in and the results will be discussed later.

As the core symptom of DCD is difficulty with coordinated movement, the children were classified into three groups according to the severity of impairment of their movement ability, as measured by the MABC2. This differentiation is important because, as Smits-Engelsman et al. (2015) found, over many pervious studies the results have been reported combining all levels of severity of movement impairment, yet we do not know if all types of severity behave the same over time. Therefore, in order to answer the research question 6.1.1 the children were classified specifically by their motor performance ability.

6.5.1 Group Classification by motor performance ability at baseline: Red, Amber and Green

The children were divided into groups using their total scores from the MABC2 at the initial testing point to ascertain the severity of the motor impairment to allow closer examination of the characteristics. The traffic light system advocated by Henderson et al. (2007) was used to classify by severity of their movement difficulties. Please refer to table 5.4 in the methodology.

In order to fully differentiate them from the other motor groups all children allocated to the Green group scored ≥25th percentile on MABC2. This was because some children scoring in the green or typical range for motor ability typical range for motor ability exhibited other atypical associated characteristics.

6.6 Differences in characteristics of Red, Amber and Green motor groups at baseline

The characteristics of the children in each motor group were documented and compared and are presented in Table 6.8. This permitted fine-grained differentiation of the children at baseline for later comparison over time.

To examine group differences across a variety of measures one-way analysis of variance (ANOVAs, or non-parametric equivalent) were used. Pairwise comparisons were used to break down significant group effects and significant main effects were analysed using post hoc tests. For all analyses, significance levels were set at .05 and Bonferroni corrections were used to control for multiple comparisons, (and Hochberg test for unequal group size).

6.6.1 Age in months:

The mean ages of each group were examined for differences at baseline (see fig. 6.5), so that any developmental differences may be accounted for at the

start of the study. The box plot (fig. 6.6) showed overlap between the median ages of the groups, suggesting no significant difference between them. However, this was tested for statistical significance. The Kolmogorov-Smirnov test showed the distribution for age was normal for Amber and Green groups, but not the Red group. However, the Shapiro-Wilk test suggested that the age for all groups was normally distributed and after examining the Q-Q plots of each group it was considered close to normal, so permitting a univariate analysis of variance (ANOVA). One-way ANOVA revealed no significant difference between groups in age [F (2,31) = 2.646, p= .087 η2 partial = .146] power .487 and post hoc test supported this.

Figure 6-5 Group means for age

Descriptive Statistics

Dependent Variable: Agemonts

group	Mean	Std. Deviation	N
sDCD	109.7000	14.29880	10
mDCD	129.1429	19.34277	7
TDC	124.0588	20.97758	17
Total	120.8824	19.86739	34

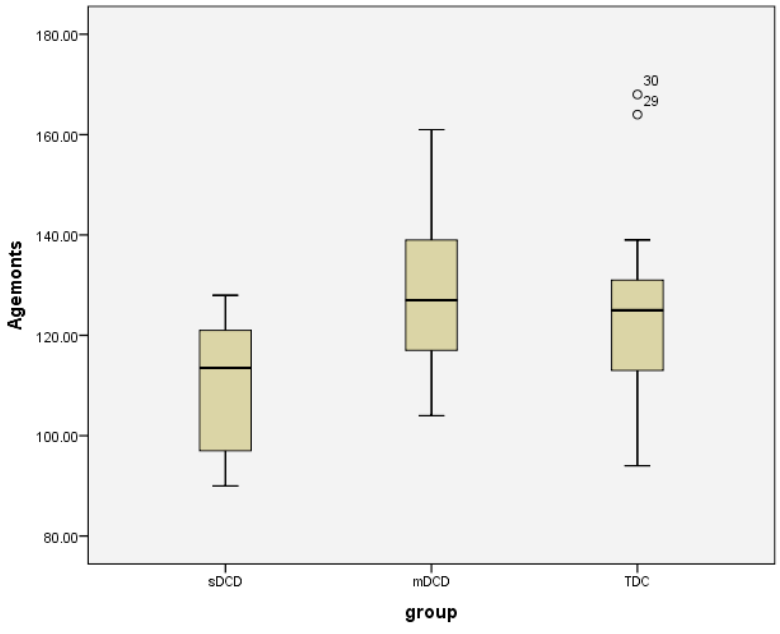


Figure 6-6 Box plot of median ages by severity of motor impairment

Summary: there was no significant statistical difference in age between the groups at baseline. Therefore, any differences in change over time during the study may not be attributed to differences in the ages of the groups, as they were not significant.

6.6.2. Presence of Associated characteristics

DCD is known to co-occur with other developmental conditions, but the extent to which this occurs was thought to vary with the severity of motor impairment and so each group was analysed and compared specifically for characteristics of impaired communication and attention. The typically developing group was also investigated (see Table 6.8).

There were a significant proportion of children who had a family history of developmental disorders in this study sample (41%), but it due to incomplete data it was difficult to ascertain if they were more concentrated in one particular group. However, the Red group had several important features; it contained no girls and had the highest proportion of children with additional associated characteristics. Therefore, in this sample, a child with severe DCD was much more likely to have associated characteristics than a child in any of the other two groups.

6.6.2.1 Associated Characteristics of the Red group (≤5th MABC2) or severe DCD

The data was based on 90% response rate of completed questionnaires.

This group of children had a very high rate of associated characteristics in addition to a much more obvious movement disorder.

Further analysis of the composition of the groups revealed more details about the potential variability and the nature of the characteristics of children with DCD. The Red group appeared to have more children with each of the associated characteristics with attention, language and communication difficulties than either of the other two groups (see Table 6.9)

Furthermore, the parents were able to identify this at a much higher rate than the other groups, 90% had their movement difficulties identified by their parents It may have been because their children already had an ASD diagnosis and 80% had two or more associated characteristics (e.g. DCD plus ASD plus ADHD characteristics). This group also had the highest rate (50%) of children identifying that they had difficulty participating in physical activity. However, one child in this group did not have any associated characteristics, was not identified with movement difficulty by his teacher, or by himself but was correctly identified by his parents. Further explanation was possible by more detailed investigation over time.

Table 6.8 Three group comparison of type of associated characteristics

	RED group ≤5th MABC2	**AMBER group 6-16th MABC2**	**GREEN group ≥25th MABC2**
SNAP IV ≤5th percentile	N=8 1 missing	N=1	N=3
CCC2 ≤5th percentile	N=9 1 missing	N=1	N=3
CSAPPA ≤5th percentile	N=5	N=2	N=2
2 or more Associated characteristics	N=8 1 missing	N=0	N=1
Only 1 associated characteristic	N=0 1 missing	N=2	N=4

Table 6.9 The number and type of associated characteristics per group at baseline

Motor ability MABC2	**Red** ≤5th percentile MABC2 n=10	**Amber** 6-16th percentile MABC2 n=7	**Green** ≥25th percentileMABC2 n=17
Number in group	10	7	17
Females	0	3	2
Males	10	4	15
ASD/ADHD/DCD	8	0	0
ASD/DCD	1	2	0
ADHD/DCD	0	0	0
ODD/DCD	0	1	0
DCD/Hear Imp	0	1	0
DCD only	1	3	0
ASD/ADHD	0	0	1
ASD only	0	0	1
ADHD only	0	0	1
SLI only	0	0	1
ODD only			1
Typical Development	0	0	12
TOTAL	10	7	17

There was also a noticeable difference in the ecological context between the groups. The Red group had a greater number of children with siblings with a developmental disorder and a higher proportion of families receiving free school meals (table 6.10) and so were at a greater disadvantage. Gillberg (2010) described this phenomenon in the ESSENCE study, whereby adversity was dose dependent. That is, the children with the more severe disorders were more likely to encounter additional disorders as well as social disadvantage.

Table 6.10 The ecological context per group

Motor ability MABC2	**Red** ≤5th percentile MABC2 n=10	**Amber** 6-16th percentile MABC2 n=7	**Green** ≥25th percentileMABC2 n=17
Free School Meals	6 (60%)	2 (28.6%)	8 (47.1%)
Sibling with dev dis	4 (40%)	2 (28.6%)	5 (29.4%)

6.6.2.2 Associated characteristics of the Amber group (6-16th MABC2) moderate DCD

Clearly, this group of children had fewer associated characteristics and, although they encountered movement difficulties, they were less severe and less obvious to their parents and to themselves. Only 28.6% had their movement difficulties identified by their parents. Perhaps they were able to circumvent the movement difficulties because most children did not have the additional difficulties in attention and communication. Only one child had difficulties with attention and only one child had difficulties with communication, but none had two or more associated characteristics. Two identified themselves as having difficulties in participating in physical activity. Again only more investigation over time could help explain the different issues.

6.6.2.3 Associated characteristics of the Green group (≥25th MABC2) typically developing*

This group had a more mixed composition than the AMBER (moderate) DCD group. This was possibly explained by the presence of two children with a diagnosis of ASD, but who scored above the 25th percentile on the MABC2 and two children who had been identified by teachers as having movement difficulties (possibly because of another diagnosis) but who scored above the 25th percentile on MABC2. Only one child had two or more associated characteristics. However, there were also a greater number of difficulties identified by parents in this group then the previous one, perhaps with fewer additional difficulties the motor problems become more apparent. 35.3% had movement difficulties identified by their parent. However, two children no longer remained in this group on subsequent testing, demonstrating that investigation over time was important to facilitate better understanding of the issues. Interestingly, 11.8% identified themselves as having difficulties in participating in physical activity

Thus it was apparent that the three groups classified by movement ability appeared to have some differences in composition and that the RED (severe DCD) group contained a very high proportion (80%) of children with two or more associated characteristics. Their teachers and parents much more readily identified their difficulties and 50% of the children themselves identified that they had a motor problem.

A broad overview of patterns was achieved by pooling the results for severe DCD and moderate DCD, as only small numbers were involved. See Table 6.11

Summary:

It was apparent that in this study the children with DCD (motor impairment ≤ 16th percentile) were (3x) more likely to associated characteristics with attention

control (measured by SNAP IV) and communication difficulties (measured by CCC2) and 8x more likely to have two or more associated characteristics. However, some of the children ≥25th percentile on MABC2 initially identified as TDC also experienced some associated characteristics and were monitored closely. These will be discussed as they progressed over time.

Table 6.11 Pooled results for all motor impaired children compared to TDC

	DCD ≤ 16th percentile MABC2 n=17	Children ≥ 25th percentile MABC2 n=17
≤5th percentile MABC2	N=10	N=0
DCDQ ≤5th percentile	N=10	N=6
SNAP IV ≤5th percentile	N=10	N=3
CCC2 ≤5th percentile	N=10	N=3
CSAPPA ≤5th percentile	N=7	N=2
2 or more Associated characteristics	N=8	N=1
Only 1 associated characteristic	N=1	N=4

6.6.3 Cognitive ability

Another important variable between different groups of children with movement difficulty in this study was their level of IQ. Differences in levels of cognitive ability between the groups could potentially account for differences in progression over time and so all participants (n=34) were tested with the KBIT2 for their general intelligence and to give scores for non-verbal and verbal ability. In this study three children scored 2sd below mean (three children with IQ below 70). However, their motor skills were below that expected for their age or

level of intellectual ability as agreed by the special needs coordinator, the parents and an experienced occupational therapist and, for this reason, were kept in the study.

The frequency distribution of IQ for the sample was however normally distributed (see fig. 6.8) and this was confirmed by the Kolmogorov-Smirnov test D (34) = 0.106, p=0.200

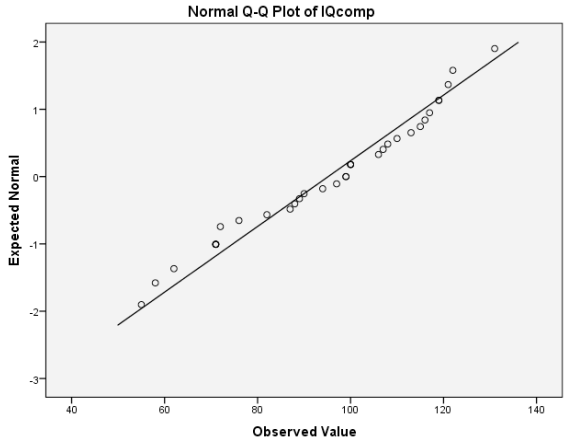


Figure 6-7 Q-Q plot of composite IQ for whole sample

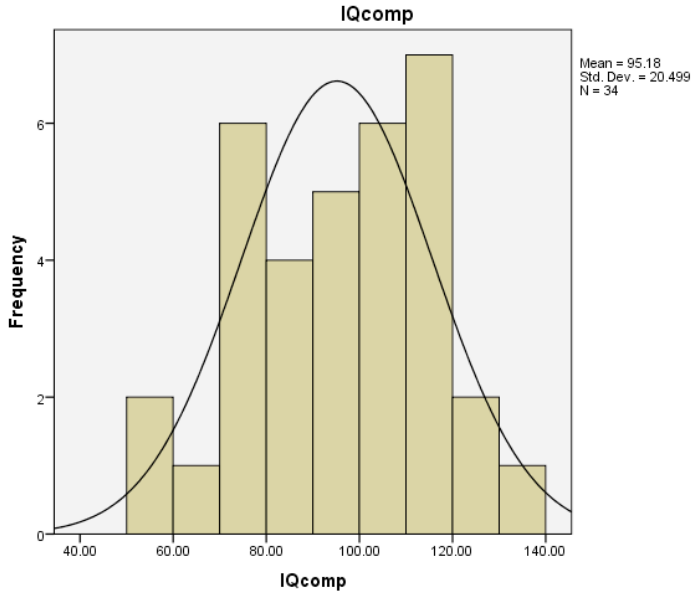


Figure 6-8 Frequency distribution of composite IQ for whole sample

Red Group: The severe (sDCD) *Group* ≤5 th *percentile on MABC2*

The mean composite IQ for this group was lower when they were compared to the other groups. Many (90%) also had associated communication and attention difficulties and previous studies have identified that groups with co-occurring conditions are likely to have a lower IQ (e.g. SLI and DCD Flapper & Shoemaker, 2013). Furthermore, children with IQ less than 70 are more likely to exhibit movement difficulties due to a developmental lag (Sugden & Wade, 2013). Indeed, Sugden & Wann (1987) found that 50% of 8 year olds with moderate learning difficulties had motor impairment compared to 5 % of TDC the same age. However, they were included in the study because their movement difficulties were over and above those expected compared to other children with similar IQ and impacted on their activities of daily living, by consensus of teacher and occupational therapist. The verbal IQ mean was the lowest in this group, perhaps not unsurprising since nine out of the 10 in this group had communication impairments as measured by the CCC2.

Table 6.12 Three group comparison of KBIT2 IQ scores

Group	***Total KBIT2 score***		***Non-verbal***		***Verbal***	
Group ≤5 th Red sDCD n=10	*Range 55-100*	*Mean 78.6 Sd (17.2)*	*Range 52-112*	*Mean 81.4 sd (19.6)*	*Range 52-99*	*Mean 80.7 sd (13.9)*
Group5-16th Amber mDCD n=7	*Range 71-122*	*Mean 91.3 sd (21.8)*	*Range 68-127*	*Mean 91.7 sd (22.6)*	*Range 79-122*	*Mean 92.6 sd (15.8)*
Group≥25th Green pTDC n=17	*Range 71-131*	*Mean 106.5 sd (14.6)*	*Range 63-130*	*Mean 101.2 sd (19.2)*	*Range 86-132*	*Mean 109.5 sd (13.4)*
Entire Group N=34	*Range 55-131*	*Mean 95.2 sd (20.5)*	*Range 52-130*	*Mean 93.5 sd (21.3)*	*Range 52-132*	*Mean 97.6 sd (18.7)*

The mean for this test 100 and standard scores between 85-115,

Amber Group: IQ results for mDCD (moderate) 5-16th percentile on MABC2

The Amber (mDCD) group had a higher mean IQ than the children in the Red group (sDCD), but the mean IQ score was still below average across all measures. However, the mean verbal IQ was marginally higher than the nonverbal mean IQ and the mean composite IQ.

Green Group: IQ results for pTDC (typical) ≥25^{h} percentile on MABC2

This group had the highest mean IQ and the smallest standard deviations of the three groups, with all the children in the average or above average IQ range, as well as the highest mean motor ability.

These measures suggest that the 'within-child' or biological characteristics of the children in the three groups were different at baseline. The Red group not only had children with a greater number of associated characteristics, but also had more children with two or more associated characteristics. Their mean IQ was lower than the other two groups, as was their mean age. Thus they appeared more impaired than the other two groups because they had the most severe motor difficulties, some learning difficulties and 80% had additional attention and communication difficulties.

Summary

Thus the children who participated in this study exhibited distinct characteristics when they were categorized by their movement ability. Furthermore, the children who exhibited characteristics of severe DCD appeared to have other difficulties in addition to their movement problems, which may include but are not limited to their capacity for learning. In addition, we have some understanding of their family context. Therefore, these differences could be quantified at the start of the study and the trajectories for these children could then be tracked to investigate what difference, if any, they had on their stability or change in motor ability and their participation in physical activity. A fine-grained analysis of IQ followed for each group to ascertain any statistical differences.

6.6.3.1 Group comparison of KBIT2 composite IQ score

The composite IQ covered a wide range of scores and as the Red (sDCD) group had a lower mean IQ than the other groups (see Fig. 6.9). It was

therefore important to ascertain if there were significant differences in IQ between the groups.

Descriptive Statistics

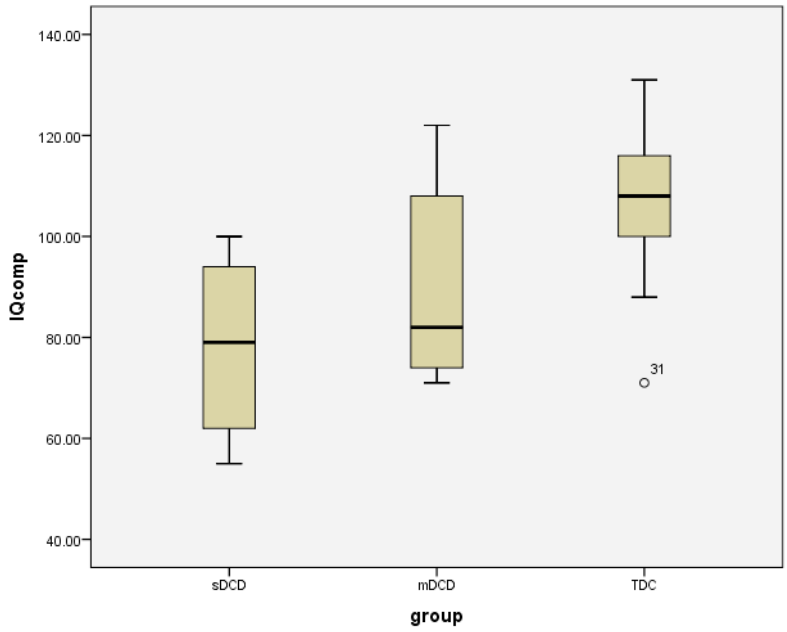
Dependent Variable: IQcomp

group	Mean	Std. Deviation	N
sDCD	78.6000	17.19948	10
mDCD	91.2857	21.47645	7
TDC	106.5294	14.56072	17
Total	95.1765	20.49903	34

Figure 6-9 Group means and SD for IQ

The box plot (Fig 6.10) of median IQ composite scores showed overlap between the scores of the Red (severe DCD) and Amber (moderate DCD) and the Amber and Green (TDC) groups, indicating less likelihood of significant difference between them. The Red and Green groups, however, showed much less overlap indicating greater likelihood of a significant difference between their composite IQ scores.

Figure 6-10 Box plot of group KBIT2 composite IQ scores



The distribution of scores across each group was tested for normality and confirmed by the Kolmogorov-Smirnov test. This enabled group comparison by ANOVA.

One-way ANOVA revealed a significant difference in composite IQ between the groups [F (2,31) = 8.864, p= .001, η2 partial = .364] power = .957

Pairwise comparisons revealed that the sDCD (Red) group had significant lower mean composite IQ than TDC group. Although the sDCD (Red) group also had a lower mean IQ than the mDCD (Amber) group it was not statistically significant (p= .137). Furthermore, the mDCD group also had a lower mean composite IQ score than the TDC (Green) group, but this only just reached statistical significance (p= .053).

Post hoc tests only revealed a statistical difference between the group means of sDCD (Red) and TDC (Green) groups (p= .001).

Therefore, in this sample the mean IQ was lowest for (Red) sDCD group and there was a significant difference between them and the TDC group. Perhaps this is not surprising since this group had the highest number of children with associated characteristics consistent with ASD and ADHD. Others have also found that these children have lower IQ scores (Flapper & Shoemaker, 2013; Kaplan, Crawford, Cantell, Kooistra & Dewey, 2006).

6.6.3.2 Group comparison of KBIT2 verbal IQ group score

The verbal IQ spanned a large range (52-132) across the sample and so the group means were investigated to determine if there was a statistical difference between the groups. See Fig. 6.11

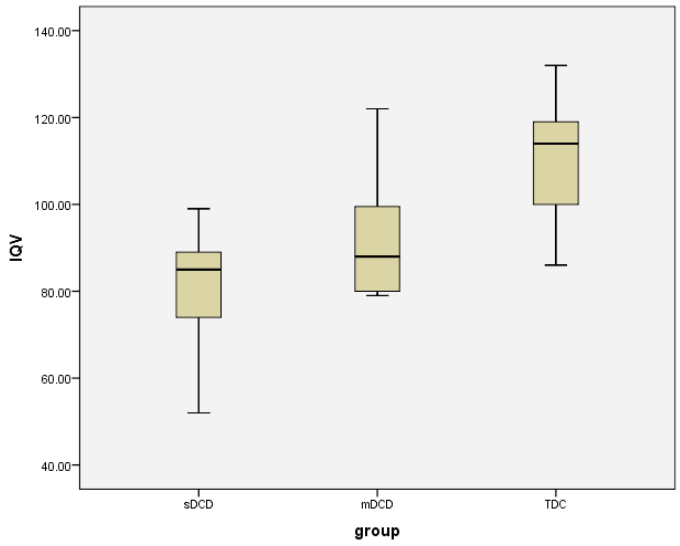
Figure 6-11 Group mean and SD for verbal IQ

Dependent Variable: IQV

group	Mean	Std. Deviation	N
sDCD	80.7000	13.91282	10
mDCD	92.5714	15.79934	7
TDC	109.4706	13.44023	17
Total	97.5294	18.71515	34

The median for the sDCD (Red) and mDCD (Amber) groups appeared close, and, despite the large range for each group, there appeared to be some overlap between the error bars for the mDCD (Amber) and TDC (Green) groups (see Fig. 6.12)

Figure 6-12 Box plot of group KBIT2 verbal IQ



A one-way ANOVA of verbal IQ between the groups revealed a significant difference [F (2,31) = 13.726, p< .001, η2 partial = .470] power = .996

Pairwise analysis revealed that the sDCD (Red) and mDCD (Amber) group means for verbal IQ were both statistically lower than TDC (Green) group

(p≤.001 and p=.012 respectively), but not statistically different from each other (p=.097). Post hoc tests supported this (p≤.001).

This indicated that there was no significant difference between the verbal IQ scores for the children in severe and moderate DCD groups. This meant that the severe DCD and moderate DCD groups means were both significantly different from the typically developing group mean for verbal IQ (measured by the KBIT2), but not significantly different from each other.

6.6.3.3 Group comparison of KBIT2 non- verbal IQ group score

The non-verbal IQ group means were investigated to determine if there was a statistical difference between the groups (see Fig. 6.13)

Figure 6-13 Group mean and SD non-verbal IQ

Dependent Variable: IQNV

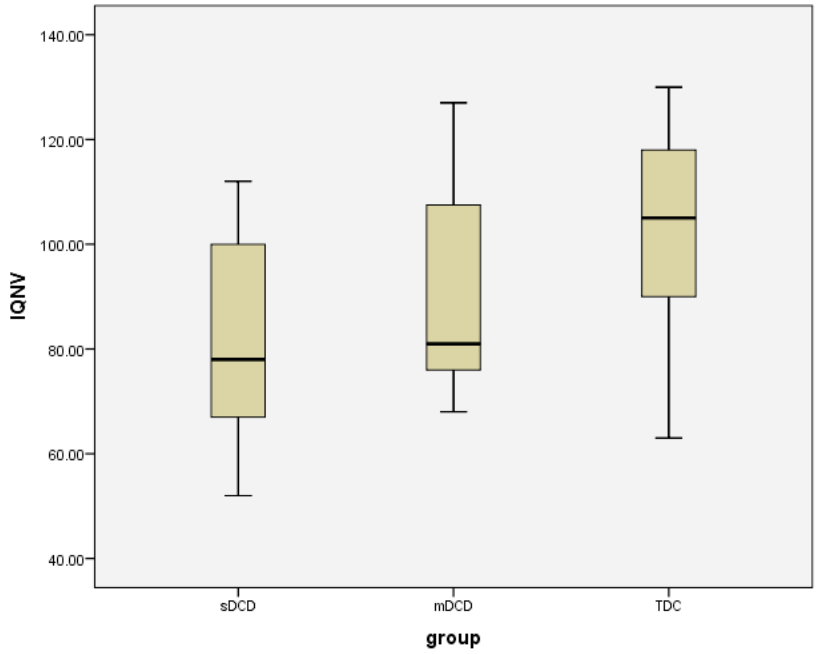
group	Mean	Std. Deviation	N
sDCD	81.4000	19.55164	10
mDCD	91.8571	22.57896	7
TDC	101.2353	19.24360	17
Total	93.4706	21.26633	34

The box plots showed overlap of error bars between all the groups and it looked unlikely that any difference would be statistically different for non-verbal IQ scores (see Fig. 6.14).

A one-way ANOVA of the mean non-verbal IQ did not reach significance between the groups [F (2, 31) = 3.119, p = .058, η2= .168] power= .558

This was confirmed by the Post hoc test Hochberg (for unequal sample sizes) that did not reach statistical significance, although the pairwise comparison of difference between sDCD (Red) group and TDC (Green) group means for non-verbal IQ was close (p= .054). Therefore, for this sample, there was no statistical difference detected between the group means for non-verbal IQ measured by the KBIT2.

Figure 6-14 Box plot of group KBIT2 non-verbal IQ scores



Summary

The children in the Red group (sDCD) had lower mean composite IQ scores than the other two groups, but only the difference between them and the Green (TDC) group reached statistical difference.

The relationship between the differences in verbal IQ group mean scores was more complex. There was a statistical difference between Red and Green group means for verbal IQ, but also a statistical difference between the Amber (mDCD) and Green groups for verbal IQ. However, there was no statistical difference between Red (SDCD) and Amber (mDCD) group means. This

indicated that the children with both severe and moderate DCD had difficulty with verbal IQ that was significantly different to the typically developing group.

A comparison of the non-verbal IQ group mean scores revealed more interesting detail. There was no detectable statistical difference between the mean non-verbal IQ scores for the three groups. This would appear to suggest that, in this sample, the children with DCD (≤16th percentile on MABC2) had difficulty specifically with verbal IQ in addition to their motor difficulties and significantly differed from typically developing children. This may have been because 85% of the sample was drawn from a school with an ASD unit attached and siblings attended the main school.

Table 6.13 Summary of mean & (SD) group characteristics at baseline

	sDCD (Red) n=10	**mDCD (Amber) n=7**	**TDC (Green) n=17**	**p**
Age months	109.7 (14.2)	129.1 (19.3)	124.1 (20.9)	.087
KBIT2 IQ	78.6 (17.2)	91.3 (21.5)	106.5 (14.6)	≤ .001*
KBIT2 VIQ	80.7 (13.9)	92.6 (15.8)	109.5 (13.4)	≤ .001*
KBIT2 NVIQ	81.4 (19.6)	91.9 (22.6)	101.2 (19.2)	.058

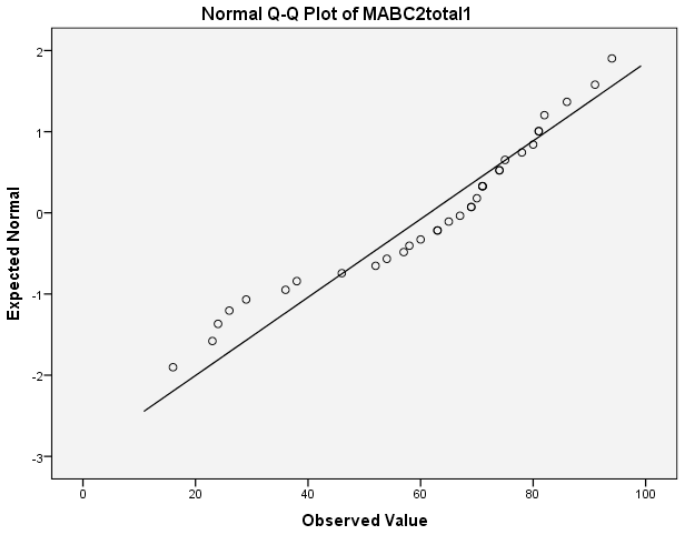
Motor difficulties, however, are core features of DCD and so the fine-grained motor characteristics of each group was analysed in more detail.

6.7 Motor characteristics of each group

The motor characteristics of the groups are described in more detail, but first the frequency distribution of the whole sample was examined to determine the appropriate type of statistical analysis.

The Kolmogorov-Smirnov test D (34) =0.145, p=0.69 did not deviate significantly from normal for the frequency distribution of the MABC2 total score for the whole sample, suggesting that it was normally distributed.

Figure 6-15 Q-Q plot of MABC2 total score for sample



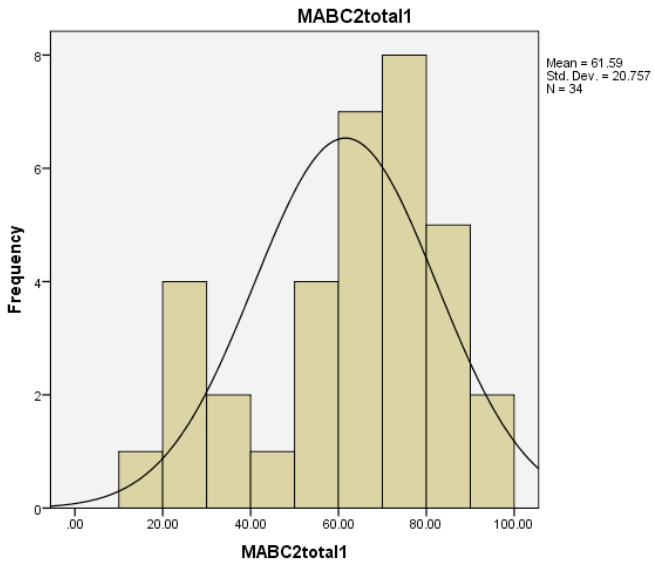


Figure 6-16 Frequency of MABC2 total score for sample

Closer investigation of the sub-groups was undertaken to determine whether inferential statistics could be used. Table 6.14 compares the descriptive statistics of each of the 3 groups.

Table 6.14 Motor characteristics of three groups at baseline

Group	***MD MABC2 score***		***A&C MABC2 score***		***Balance MABC2***	
Group ≤5 th Red sDCD n=10	*Range 4-18*	*Mean 10.7 Sd (4.1)*	*Range 8-16*	*Mean 10 sd (2.8)*	*Range 4-26*	*Mean 14.7 sd (6.9)*
Group5-16th Amber mDCD n=7	*Range 12-24*	*Mean 17.9 sd (4.5)*	*Range 10-20*	*Mean 15.1 sd (4.1)*	*Range 24-35*	*mean 28.9 sd (3.9)*
Group≥25th Green pTDC n=17	*Range 19-32*	*Mean 26.1 sd (3.9)*	*Range 12-28*	*Mean 18.1 sd (4.3)*	*Range 25-39*	*mean 33.3 sd (3.6)*
Entire Group N=34	*Range 4-32*	*Mean 19.9 sd (7.9)*	*Range 8-28*	*Mean 15.1 sd (5.2)*	*Range 4-39*	*Mean 26.9 sd (9.5)*

- Red Group: The children who scored in the severe (sDCD) range had the lowest scores in all subtests. However, the relatively small standard deviation for aiming and catching (2.8) indicated that all scores were close to the very low mean for this subtest and showed that all the children performed poorly. This item depends, to a certain extent, on learned skills and experience and unsurprisingly the children in this group performed poorly. This group had mean scores in all of the subsections ≤5th percentile, which indicated motor problems in all areas.

- Amber Group: The children who scored in the moderate (mDCD) range performed better across all subtests. However, there was quite similar overlap to the scores for the children with severe (sDCD) in the range for manual dexterity and aiming and catching (both were ≤5th percentile), which indicated severe problems, but not for balance. This group had better mean balance.
- Green Group: The children who scored in the TDC range clearly had much better movement ability, shown by their higher mean scores. However, only their mean balance score attained the 50th percentile, indicating that mean manual dexterity and aiming and catching were below average.

Summary: The three groups appeared to have different motor characteristics at baseline. However, there was some overlap between the Red and Amber groups for manual dexterity, as well as between the Amber and Green groups, for this subtest. Additionally, there was large overlap between all three groups for aiming and catching, making distinction between them harder. However, there were clearer distinctions in the mean scores for balance between all three groups. Of course any differences needed to be verified by statistical analysis.

Statistical analysis

Using a calculation with α =0.05 and power of 0.8, a sample size of a minimum of 9 per group was required to compare groups for children in this sample (http://statisticalsolutions.net/pss_calc. phpsoftware package). The Red and Green groups had sufficient numbers per group (10 and 17 respectively), but the Amber only had 7 at baseline. Although the tests were run the Amber group results were interpreted with caution because of the small sample in this group.

6.7.1 Group comparison of MABC2 total score at baseline

A test for normality of the MABC2 data was first undertaken for each group to determine if parametric tests were appropriate. The Kolmogorov-Smirnov test

showed the scores across all groups were normally distributed for the MABC2 total score and so an ANOVA was used to compare group difference.

An ANOVA assumes equal variance for each group, however this was not the case for the MABC2 total scores with this sample. Levene's test was significant, which indicated that equal variance had been violated. However, Field recommends using Welch or Brown-Forsythe statistic in this case to account for this (Field, 2013, p461). Significant group effects were broken down using pairwise comparisons and significant main effects were broken down using post hoc tests.

One-way ANOVA revealed significant differences between the groups

MABC2 total score [$F(2,31) = 71.351$, $p \leq .001$, $\eta 2$ partial = .822] power = 1

This difference is unsurprising, since the groups were classified using this score.

Pairwise comparison revealed sDCD<mDCD<TDC and post hoc analysis (Bonferroni and Hochberg for unequal sizes) showed significant differences between sDCD (Red) and mDCD (Amber) groups and sDCD (Red) and TDC (Green) groups ($p \leq .001$) and the difference between mDCD (Amber) and TDC (Green) groups was also significant ($p = .002$).

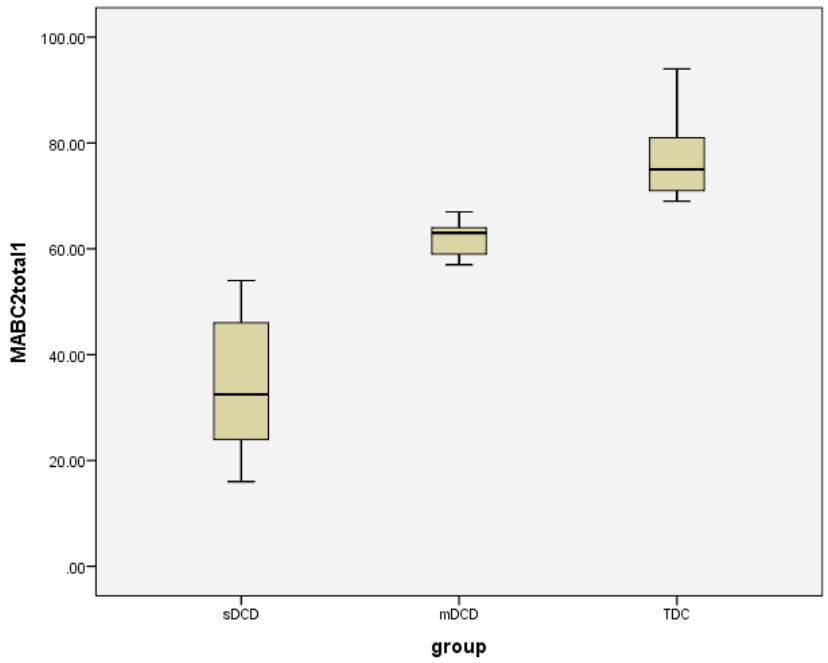


Figure 6-17 Box plots of three group median of MABC2 total score at baseline

6.7.2 Group comparison of Manual Dexterity at baseline

The manual dexterity scores were normally distributed at baseline and so permitted parametric tests.

A one-way ANOVA revealed significant difference between the groups for manual dexterity [F (2, 31) = 45.503, p≤ .001, η2 partial= .746] power = 1

Pairwise comparison revealed sDCD<mDCD<TDC and post hoc (Bonferroni and Hochberg) analysis revealed significant differences between sDCD (Red) and TDC (Green) groups and mDCD (Amber) and TDC (Green) groups (p≤ .001) and sDCD (Red) and mDCD (Amber) groups (p= .004).

This can be clearly seen by very little overlap of the groups on the box plot (Fig. 6.18). Therefore, in this sample, the manual dexterity characteristic of the three groups is distinctly different at baseline.

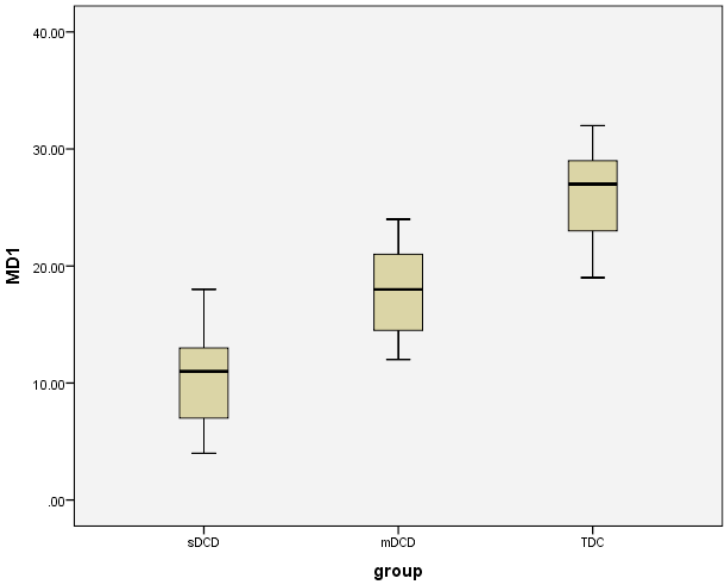


Figure 6-18 Box plots of Manual dexterity score at baseline

Manual dexterity is required for school related tasks such as handwriting, tool use and self-care. A child experiencing difficulty in one of these areas is one of the most common reasons for teacher referral to community occupational therapy services. Interestingly, both the Red (sDCD) and Amber (mDCD) groups had difficulty with manual dexterity and were significantly different to the TDC (Green) group. However the Red (sDCD) group had the lowest mean and was still significantly different to the Amber (mDCD) group mean.

6.7.3 Group comparison of Aiming and catching at baseline

Aiming and catching are key skills for team play and most ball games, both of which are important for playground participation with peers, particularly for boys at primary school age. The extant literature has highlighted these as problem areas for children with DCD and so investigation of group difference here was important.

One-way ANOVA revealed significant differences between the groups [F (2,31) = 13.607, p≤ .001, η2 partial = .467] power .996

Pairwise comparison with post hoc analysis (Hochberg test & Bonferroni) revealed significant difference between sDCD (Red) and mDCD (Amber) groups (p= .035) and sDCD (Red) and TDC (Green) groups (p≤ .001) but not between the mDCD (Amber) and TDC (Green) groups (p= .266 & p= .299).

Red (sDCD) group performed significantly worse than both the Amber (mDCD) group and Green (TDC) groups. However, the Amber and Green groups did not show a significant difference in their aiming and catching scores. This is demonstrated by the large areas of overlap on the box plots (Fig. 6.19) of the Amber and Green groups below. This could either mean that the Amber group is performing close to typically developing or that the Green group is performing at the lower end of normal. From the appearance of the error bars, the latter is more likely.

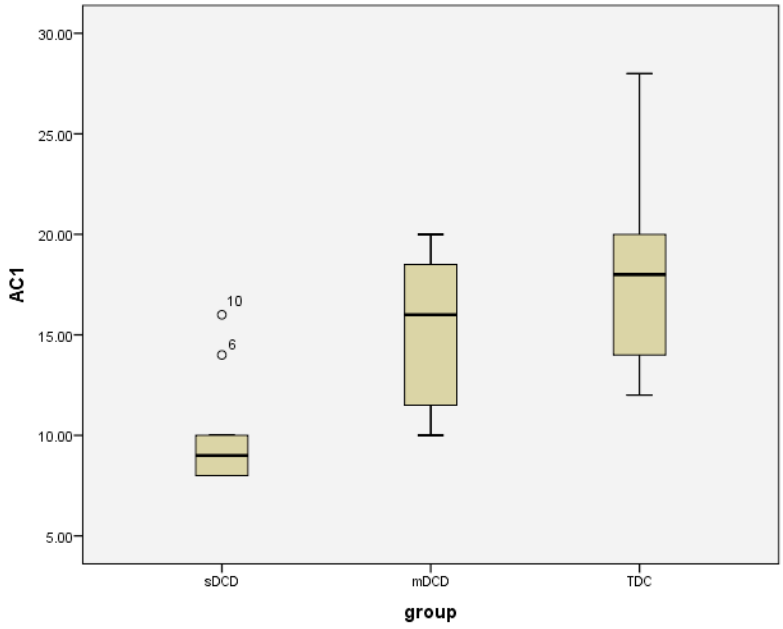


Figure 6-19 Box plots of Aiming & catching at baseline

These results showed that the Red (sDCD) group encountered the greatest difficulty with ball skills. This would be barrier to their participation in playground activities and team sports. Interestingly, there was no significant difference between the mean aiming and catching for the Amber (mDCD) and Green (TDC) groups, making their profiles more similar. However, both means were

quite low for these skills and may have reflected the context of deprivation and possible lack of opportunities.

6.7.4 Group comparison of Balance at baseline

Balance is a fundamental skill for controlled movement and impaired balance can negatively impact on many aspects of participation in physical activity. Group means are presented in fig. 6.20

Again the Amber (mDCD) group profile appeared more similar to the Green (TDC) group than to the Red (sDCD) group. This was confirmed by statistical analysis.

Dependent Variable: B1

group	Mean	Std. Deviation	N
sDCD	14.70000	6.929005	10
mDCD	28.85714	3.976119	7
TDC	33.29412	3.618783	17
Total	26.91176	9.449604	34

Figure 6-20 Group mean and SD of Balance at baseline

One-way ANOVA revealed significant differences between the groups [F (2,31) = 46.517, p≤ .001, η2 partial = .750] power = 1

Pairwise comparison with post hoc tests (Hochberg & Bonferroni) revealed significant differences between sDCD (Red) and mDCD (Amber) and sDCD (Red) and TDC (Green) groups (p≤ .001) but not between mDCD (Amber) and TDC (Green) groups (p= .144 & p= .154). The Red (sDCD) group performed significantly worse than both the Amber (mDCD) group and Green (TDC) groups. They also showed that the Amber group performed worse then the Green group, but this did not reach statistical significance. Therefore, the Red (sDCD) group balance was clearly distinguishable from the other two groups.

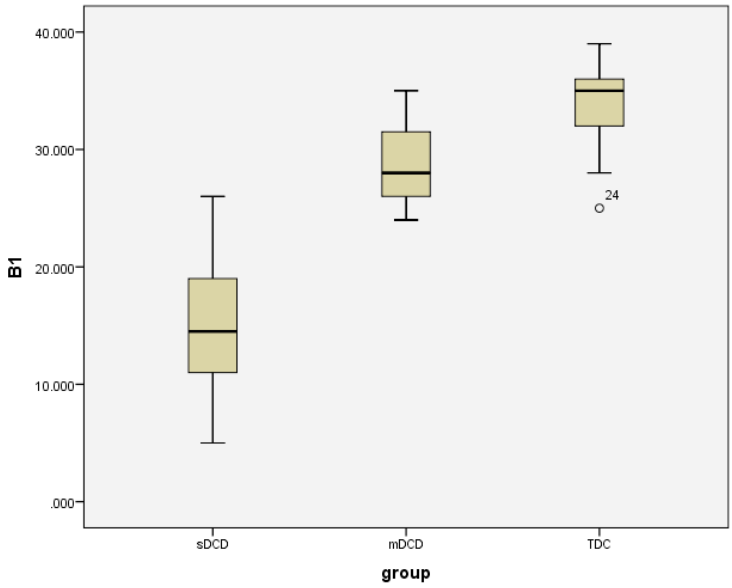


Figure 6-21 Box plots of group median balance at baseline

Balance is a fundamental movement skill essential for participating in PA. Interestingly the Amber and Green groups balance looked more similar to each other.

6.7.5 Summary of group motor ability performance at baseline

It is evident from these results that sDCD (Red) and TDC (Green) groups were statistically different on all motor subtests of MABC2. Moreover, the sDCD (Red) group was also statistically significantly different to the mDCD (Amber) group on all subtests. However, despite the mDCD (Amber) and TDC (Green) groups having statistically significant difference in their manual dexterity scores, they were more similar in their mean aiming and catching and balance scores. Only the Red group performed significantly worse than the other two groups in all motor scores at baseline, demonstrating problems across all motor domains. In other words, the Amber and Green groups, in this sample, were more similar to each other than to the Red group. This may have occurred because the Green group mean was low for aiming and catching (possibly as a result of most of the sample residing in an area of high deprivation). The sDCD (Red) group had a distinctive motor profile, which was clearly distinguishable from the

other two groups at baseline, with motor difficulties across all areas. The Amber (mDCD) group, although they clearly had distinct difficulties with manual dexterity, was much less distinguishable from the TDC (Green) group for balance and aiming and catching.

Table 6.15 Summary of comparison of group motor characteristics at baseline

	sDCD (Red)	**mDCD (Amber)**	**TDC (Green)**	**p**
MABC2 total score	34.4 (13)	61.9 (3.7)	77.5 (7.6)	≤ .001*
Manual dexterity	10.7 (4.1)	17.9 (4.5)	26.1 (3.9)	≤ .001*
Aiming & catching	10 (2.8)	15.1 (4.2)	18.1 (4.3)	≤ .001*
Balance	14.7 (6.9)	28.9 (4.0)	26.9 (9.4)	≤ .001*

6.8 Group comparison of the parent rated DCDQ (07)

DCD is known to interfere with daily life and the DCDQ (07) invites parents to identify motor difficulties and rate the impact they are having on their child. The DCDQ (07) group mean for the Red (sDCD) group was lower than the other two groups, as expected, because they had more severe motor impairment. However, the Amber (mDCD) and Green (TDC) DCDQ (07) group means were very similar. This was not predicted, since the Amber group had poorer motor performance than the Green group and thus it was expected to have had a greater impact on their daily life. Statistical comparison was undertaken to determine significant differences.

Only the total score was used for analysis, since previous factor analysis of the subtests in the DCDQ (07) indicated poor reliability (Cairney et al., 2008). However, it allowed comparison of the parent ratings by group. The 5 % cut off scores for identifying potential DCD were:

Suspect DCD when total score is ≤55 for under 10 and ≤57 for over 10 years old.

Descriptive Statistics

Dependent Variable: DCDQ

group	Mean	Std. Deviation	N
sDCD	30.2222	12.23497	9
mDCD	62.4000	10.59717	5
TDC	58.2353	17.04600	17
Total	50.7742	19.76480	31

Figure 6-22 Group mean DCDQ '07 scores

6.8.1 The Red group (sDCD): all scored ≤5 th percentile on MABC2

The response rate of return of the DCDQ (07) was 90% for the Red group and 100% of those returned indicated identification of movement problems by the parents. The DCDQ (07) scores ranged from 15 – 56. The movement difficulties were subsequently confirmed by individual assessment with the MABC2. 90% of this group had two or more associated characteristics and the entire group was boys.

6.8.2 The Amber group (mDCD): all scored 6-16th percentile on MABC2

The response rate was 71.4% for this group, 5 out of 7 DCDQ (07) forms were returned. This group had the largest number of girls, 3 (42.9%). Of the returned forms one set of parents rated their child with movement difficulties and this child also had a diagnosis of ASD. The DCDQ (07) scores in the group ranged

from 46 – 72, despite 42.9% of the children only attaining 9th percentile on MABC2 at baseline. 42.9% (3 children) of this group had one known associated characteristic, but none had 2 or more.

6.8.3 The Green group (TDC): all scored above 25th percentile on MABC2

The response rate was 100% for DCDQ (07) for this group. 5 of the group had one associated characteristic (29.4%), 2 boys with ASD, one with ADHD, one with SLI and one with ODD. Three children (17.6%) were identified at risk of DCD by their parents. One of these had ASD, another ADHD and the 3rd was a looked after child with no diagnosis. Of the three, only the child (he had ADHD) remained in the Green group over time. The other two went on to display movement difficulties and changed category on MABC2. A third child in the Green group, not identified by DCDQ (07), went on to display movement difficulties and changed group over time. The range of DCDQ (07) scores were large (15 – 75) and this was possibly due to the presence of children with associated characteristics.

6.8.4 Statistical analysis of DCDQ (07)

The Kolmogorov-Smirnov test revealed that the DCDQ scores were normally distributed. However, the Shapiro-Wilk test suggested that the Green group with the typically developing children DCDQ scores were not normally distributed. However, Q plots suggested the frequency of scores were close to normal and therefore ANOVA was run to explore difference between groups.

One-way ANOVA revealed a significant difference between the groups [$F(2, 28) = 12.060$, $p \leq .001$, $\eta 2$ partial= .463] power = .991

Although pairwise comparison showed a significant difference between Red and Amber and Red and Green groups ($p = .001$ and $p \leq .001$ respectively), the difference between Amber and Green groups did not reach statistical

significance (p= .589). Post hoc analysis with Bonferroni and Hochberg's test (for unequal size) supported this. Therefore, the Red group appeared quite distinctive from the other two groups on a measure of parent rated motor difficulties. The Amber and Green groups were indistinguishable from each other, with parents from both groups identifying some difficulties, but not as much as the parents from the Red group. This is illustrated in fig. 6.23

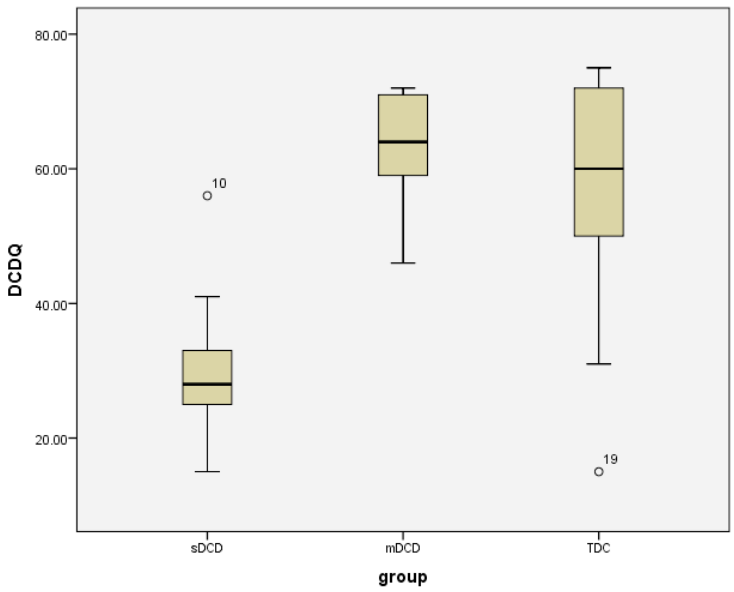


Figure 6-23 Box plots of group median DCDQ '07 scores

Summary

The children with severe DCD (Red group) were distinct from the other two groups. Their parents could identify severe motor difficulty that interfered with daily life. The difference in mean scores for DCDQ (07) between the Red group and the other two groups was statistically different. The entire Red group was boys and 90% had two or more associated characteristics, which may have helped to highlight the motor problems to a greater extent. The Amber and Green groups did not appear to be distinct from one another in the way that the parents rated their children on DCDQ (07). This may be because the motor difficulties were subtler and there were fewer children with any associated characteristics. Of interest was that the children identified with motor problems by DCDQ (07) in the Amber and Green groups, all but one had associated characteristics, and he was fostered and had unknown early development. The

Amber group also contained three girls and perhaps parental expectations for motor competence is less for girls. Another possible explanation is the small number of responses (5) for the Amber group, making statistical comparison much less reliable. However, once again there was a difference between the Red group and the other groups at baseline and this was reflected in how the parents rated the children on the DCDQ (07).

6.9 Group comparison of the child rated CSAPPA

This measure of child self-perception towards physical activity (PA) is considered to identify those children with motor difficulties thought to be at risk from DCD by detecting the children with low scores in adequacy, predilection and enjoyment of PA (Hay, 1992). The extant literature indicates that children with DCD often have lower self-perceptions and this can influence actions and participation in PA. It was therefore predicted that Red (sDCD) and Amber (mDCD) groups would significantly differ from the Green (TDC) group in their self-perception scores on the CSAPPA. However, the group means in this sample were quite similar for all three groups (see Fig. 6.24).

Descriptive Statistics

Dependent Variable: CSAPPA1

group	Mean	Std. Deviation	N
sDCD	55.4444	12.35021	9
mDCD	56.4286	17.20327	7
TDC	62.7647	11.13289	17
Total	59.4242	12.95914	33

Figure 6-24 Group mean CSAPPA scores at baseline

The CSAPPA permitted the children to rate themselves in their enjoyment of, predilection to take part in and their perceived adequacy in PA. It was therefore important to investigate if there were any differences between the groups. The 5% cut-off scores for the CSAPPA were used. These were a score of <47 for

males and a score of <55 for females, to indicate possible motor difficulties. The maximum score was 75.

6.9.1 The Red group (sDCD) ≤ 5th percentile on MABC2:

The total scores from the CSAPPA ranged from 32-74. Despite their poor motor performance on the MABC2 (range 0.1 -5th percentile), 80% of these boys indicated that they enjoyed physical activity, were happy to take part and felt that their performance was adequate. This may have reflected their age (7-10 years) and the motor demands of the activities they liked (all are primary school age), a lack of self-awareness or conversely, a real delight in physical activity. Only by noting stability or change over time would ascertain which reason was more likely. 20% of the boys described hating P.E. and rated their perception of enjoyment, predilection to take part and participation in PA poorly. Of particular interest was that their CSAPPA scores appeared unrelated to the MABC2 scores.

6.9.2 The Amber group the 6-16th percentile on MABC2:

The children who score in the 6-16th percentile on MABC2 presented a different picture. The total CSAPPA scores ranged from 43-75. This group contained three girls approaching or beginning adolescence. All the girls stated that they enjoyed physical activity, but one 11 year old expressed that she did not rate her adequacy highly and fell with in the suspect motor impairment range on the CSAPPA.

The other child who scored within the suspect DCD range was a child who had an ASD diagnosis and expressed that he hated P.E. The remaining five children all stated that they enjoyed PA and stated that they felt reasonably competent despite scoring in the at risk range for motor impairment. The ages in the group ranged from 9-13 years and again the CSAPPA scores and the MABC2 scores appeared unrelated for this group too.

6.9.3 The Green group (TDC) > the 25th percentile on MABC2:

All the children in the Green group expressed enjoyment and a positive attitude to predilection and adequacy in PA, with the exception of one child. This child scored 36, which specified that he did not enjoy physical activity and indicated suspect motor impairment, despite his score of 50th percentile on MABC2. He had a diagnosis of ASD and was afraid of being hit by a ball in the playground and over time he scored in the impaired range on MABC2.

Table 6.16 CSAPPA scores by Red, Amber and Green group

	sDCD (Red)	**mDCD (Amber)**	**TDC (Green)**
CSAPPA mean (SD)	55.4 (12.4)	56.4 (17.2)	62.8 (12.95)
Range	32-74	43-75	36-75

These results were examined in more detail as the children progressed over time within the context of their family circumstances and are discussed later.

6.9.4 Group comparison of group CSAPPA scores at baseline

A test for normality of the data was carried out to determine if parametric tests were appropriate to compare the group means. The Kolmogorov-Smirnov test showed that the scores were distributed normally across all groups, and demonstrated by Q plots and so parametric tests could be used.

However, contrary to the prediction, one-way ANOVA revealed no significant difference between the groups on CSAPPA mean scores [F (2,30) = 1.190, p= .318, η2 partial= .074] power = .240

Furthermore, pairwise comparison revealed no significant differences between any of the groups and post hoc analysis supported this. Thus there appeared to be no significant difference in self-perception of adequacy, predilection or

enjoyment of PA between the groups, despite quite distinct differences in their actual motor performance ability. Motor performance ability may not have been the most important factor in determining self-perception for these children.

The box plots (Fig. 6.25) illustrated the median for the groups were similar. This was unexpected as much of the extant literature highlights low self-perception in motor and other areas for children with DCD. Further analysis over time revealed some interesting findings and will be discussed later.

Summary

It appeared that, despite vastly differing motor performance ability, some children in each group indicated an enjoyment and predilection to take part in PA. Furthermore, that they rated their performance in PA as adequate, despite their low MABC2 scores. On an individual basis the MABC2 scores appeared unrelated to the CSAPPA rating and suggested the possibility of other factors at play. Only further investigation over time would help uncover potential causes.

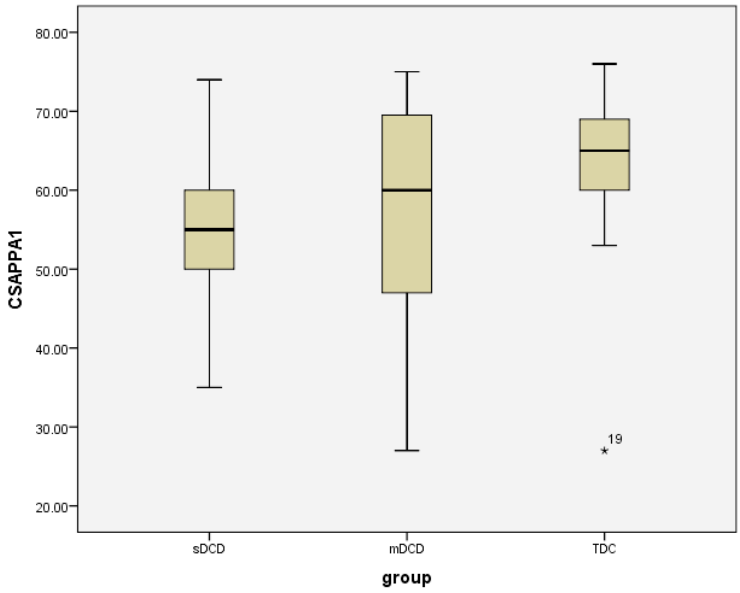


Figure 6-25 Box plots of group CSAPPA at baseline

Table 6.17 Summary of group comparison of DCDQ '07 and CSAPPA at baseline

	sDCD (Red)	mDCD (Amber)	TDC (Green)	p
CSAPPA	55.4 (12.4)	56.4 (17.2)	62.8 (12.95)	.318
DCDQ (07)	30.2 (12.2)	62.4 (10.6)	58.2 (17.0)	≤ .001*

The Red (sDCD) group have very distinctive characteristics and significantly differed from the other two groups in a number of ways. Furthermore, the parents of the children in the Red group could more easily identify motor problems that their children encountered. However, the groups were indistinguishable from each other by the children's self-perception of their adequacy, predilection and enjoyment of physical activity. Whilst these results must be interpreted with caution due to the small sample size of the Amber (mDCD) group, preliminary findings suggest that the children in the severe DCD (Red) group not only possess significantly different characteristics from typically developing children (Green group), but also from children with moderate DCD (Amber group) for large effect size.

6.10 Summary of characteristics at baseline with parametric test results

1. Age: There was no significant difference between the groups in age

2. Self-perception of motor performance (CSAPPA): There was no significant difference between the groups CSAPPA scores.

3. Motor performance ability (MABC2): There was a significant difference between the all groups for MABC2 total score and manual dexterity score, but only a significant difference between Red and Green groups for aiming & catching and balance

4. IQ (KBIT2): There was only a significant difference between Red and Green groups for composite IQ score and between Red and Green and Amber and

Green groups verbal IQ scores. The non-verbal IQ scores did not reach statistical significant difference for any group.

5. Impact on daily life (DCDQ 07): There was a significant difference between Red and Amber and between Red and Green groups, but not Amber and Green groups.

6.11 Non-parametric test results at baseline

As previously described, some of the assumptions for parametric tests were not met in the data, for example, the sample size for the Amber group was small and the sample was not random, therefore the Kruskal-Wallis non-parametric test was also undertaken. However, the results supported those of the parametric tests (see Fig. 6.26).

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of MABC2total1 is the same across categories of group.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
2	The distribution of IQcomp is the same across categories of group.	Independent-Samples Kruskal-Wallis Test	.003	Reject the null hypothesis.
3	The distribution of IQNV is the same across categories of group.	Independent-Samples Kruskal-Wallis Test	.071	Retain the null hypothesis.
4	The distribution of IQV is the same across categories of group.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
5	The distribution of MD1 is the same across categories of group.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
6	The distribution of AC1 is the same across categories of group.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
7	The distribution of B1 is the same across categories of group.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
8	The distribution of CSAPPA1 is the same across categories of group.	Independent-Samples Kruskal-Wallis Test	.273	Retain the null hypothesis.
9	The distribution of Agemonts is the same across categories of group.	Independent-Samples Kruskal-Wallis Test	.086	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Figure 6-26 Kruskall-Wallis non-parametric test summary

6.12 Correlations at baseline

Pearsons correlations were performed to identify any relationships between the variables at baseline, since the data followed a normal distribution.

There was a significant correlation between MABC2 and IQ composite score r= 0.648, significance value 0.01. This was not surprising since the group mean

IQ was below average and it is well known that children with lower IQ are more likely to encounter poorer motor performance (Sugden & Wann, 1987; Sugden & Wade, 2013). A weaker correlation was found between CSAPPA and MABC2 r=0.358 significance value 0.05 and again this was not surprising as the content validity of both measures is similar (Hay et al., 2004). However, there was no significant relationship between CSAPPA and IQ.

The CSAPPA correlated weakly with the aiming and catching and balance components of the MABC2 but not the manual dexterity component, r=0.345 and r= 0.365 respectively at significance level 0.05. Both those components are required for physical play, whereas manual dexterity is less important for physical activity play.

The correlation between CSAPPA and IQ was non significant and the correlation between CSAPPA and age did not reach significance.

Table 6.18 Correlations strongly significant (p= .01 two tailed)

Correlations	**Pearson's r**	**Significance p (two tailed)**
MABC2 and IQ	r= .648	P< .001
MABC2 and DCDQ 07	r=. 686	P< .001
DCDQ 07 and Age	r=. 517	P= .003
CSAPPA and DCDQ 07	r=. 553	P= .001

Table 6.19 Correlations weakly significant (p=.05 two tailed)

Correlations	**Pearson's r**	**Significance p (two tailed)**
CSAPPA and MABC2	r= .358	P= .041
CSAPPA and A&C	r=.346	P= .049
CSAPPA and Balance	r= .365	P= .037
CSAPPA and IQ	r= .058	P= .748 NS
CSAPPA and Age	r= .341	P= .052 NS

6.13 Summary of part I results

Part 1 of the results from this study addressed the research question 5.1.1 'What are the characteristics of children with different severities of DCD compare to children without DCD?'

In summary, by using Bronfenbrenner's Bio ecological model to assess the meso-system, the findings suggested that context of the motor impaired group did not differ greatly in their home and family circumstances from the non-impaired motor group. In fact, the motor impaired group appeared to have slightly more favourable environmental contexts in terms of parent employment, car ownership and positive parent attitude to PA.

However, with more detailed analysis (when classified by severity of motor ability) the three groups had differences in the number of associated characteristics present, their IQ composite scores, handwriting difficulties, and level of special educational needs. The children in the Red group (most severe motor problems) had the most additional difficulties, with 80% having two or more associated characteristics. They also had statistically significantly different motor profiles to the other two groups in their group mean manual dexterity, aiming and catching and balance scores on MABC2. Furthermore, their parents were easily able to identify their motor problems and the functional impact on their daily life. This appeared to indicate that the 'within-child' or biological characteristics of this group might have been distinct or different to those of the other groups.

However, there was no significant difference in age, non-verbal IQ or self-perceptions of participation in PA (CSAPPA scores) between the groups at baseline. Furthermore, there were no significant correlations between the children's CSAPPA scores and either their age or IQ. Which would seem to indicate that the scores reflected their perceived enjoyment, adequacy and predilection to take part in PA, rather than their actual motor ability or misunderstanding of the questionnaire or the notion that only younger children

enjoy uninhibited PA. By noting these similarities and differences at baseline it was possible to follow the progression of children with and without DCD over time and compare the groups.

The children were then followed over two academic years to investigate stability or change in their motor characteristics and their self-perception of enjoyment, predilection and adequacy in PA.

6.14 RESULTS PART II: Change over time

This study aimed to describe the different profiles of children with and without DCD and identify any differential stability or change in motor ability over time between them. Group difference in motor change was investigated simultaneously with difference in the consistency in self-perception of motor ability, enjoyment and predilection to take part in physical activity over time. It was hypothesized that the children with the lowest motor ability would have the lowest scores in self-perception over time. The preceding chapter has described the fine-grained analysis of the profile of characteristics of children with and without DCD at the baseline in order to answer the research question "what are the characteristics of children with different severities of DCD compared to children with out DCD?" The baseline results showed that there were significant differences between the groups for children with different severities of motor ability. There now follows an analysis of how children with the different profiles performed over time in terms of their motor stability or change, together with consistency in their self-perception over time.

This will address research questions:

- How stable are the motor characteristics or do they change over time?
- How consistent are their self-perceptions of adequacy, enjoyment and predilection to take part in physical activity or do they change over time?

The investigations in part I of the study, which examined differences in profiles of the children, included presence or absence of associated characteristics and the degree of severity of motor difficulty at the baseline measurement. This led to the subsequent classification into groups: Red group where children scored ≤ 5th percentile on MABC2 (sDCD), Amber group where they scored 6-16th percentile on MABC2 (mDCD) and Green group where they scored ≥25th percentile on MABC2 (TDC) using the MABC2 traffic light classification, as previously described. The findings indicated that three groups had distinctive characteristics and some differences at baseline. The following section

explores the pattern of stability or change in motor performance ability over time of these groups, to establish whether the children with different severities of DCD progressed differently from each other, or from typically developing children. Change in motor ability was ascertained by repeated measures of the MABC2.

However, in order to avoid any contention over test re-test reliability of the MABC2, three different methods of analysis were undertaken. 1) Examining the smallest detectable change in motor performance, taken as a change ≥10 points in total score of MABC2 (Holm et al., 2013). 2) Examining any change in group membership and the distribution of children with associated characteristics in the groups and 3) Examining any statistically significant difference between the groups, by comparing the progression of the groups based on their membership at baseline.

The analyses first examined the smallest detectable change (SDC) in MABC2 total score over three data points. This is a measure thought to indicate an observable change in everyday motor performance, as opposed to only recording a small changed score on a standardized test. Holm et al., (2013) reported this change as 10 points or more on MABC2 total score when measured by the same tester. This was followed by any examining any change in group membership (Red, Amber and Green) over time, and an examination of the distribution of children with associated characteristics in each of the groups. Finally, any group difference in motor progression, using MABC2 scores, was analysed using repeated measures analyses of variance (ANOVA). Significant group effects were broken down using pairwise comparisons, significance levels were set at 0.05 and Bonferroni corrections used to control for multiple comparisons.

6.15 Prospective study of motor ability and attrition rate

The investigation of motor performance ability spanned three data points over two academic years for all the children and, additionally, specific cases were

selected for a 4th data point for closer inspection. The same experienced occupational therapist took repeated measures of the MABC2, for all children remaining in the study.

Of the 34 children measured at baseline (T1), the attrition rate was 9% at data point two (T2) as two children at a secondary school were unable to be re-tested and one child left a primary school to be home schooled. It reached 15% by data point three (T3) with two more children who moved schools, leaving 29 children at the end of the study.

6.16 Investigation of stability or change in motor performance ability over time

6.16.1 Smallest detectable change (SDC) in MABC2 total score

The total test score from MABC2 was used to measure change in motor performance ability. However, the smallest detectable motor behaviour change was also noted and was referred to as the smallest detectable change (SDC).

This study adopted the method described by Holm et al. (2013), where change in measurement of + or – 10 points in the total test score of MABC2, when the re-tests were performed by the same tester. This method reduced the possibility of measurement error and enhanced the reliability of the results.

Change was measured between baseline MABC2 score (T1) and score at data point three (T3). Missing data was only included if two data points had been collected and in those two cases the difference between T1 and T2 was used. Table 6.20 displays the stability or smallest detectable change (SDC) in total MABC2 test score for each of the Red, Amber and Green groups.

Table 6.20 Motor change T3-T1 (MABC2 total score) over time by group

	SDC ≥10 points on MABC2 total score (Holm et al., 2013)		
Groups	Improved	Same	Deteriorated
Red (sDCD) n=9	2 (22.2%)	7 (77.8%)	0 (0%)
Amber (mDCD) n=5	5 (100%)	0 (0%)	0 (0%)
Green (pTDC) n=17	4 (23.5%)	9 (53%)	4 (23.5%)

Each group was analysed in turn and there now follows a description of the results.

6.16.2 Motor change in the Red group (sDCD)

One child was lost to follow up, but of the remaining nine children, the predominant picture for this group was stability of motor performance ability over time. Nearly 78% stayed the same (i.e. the MABC2 total score difference ≤10 points). None of the children deteriorated and 22% improved their motor performance ability over time. However, their improvement was not sufficient for them to change motor category and so all the children remained in the Red group over time. In other words, the entire Red group remained in the lowest 5th percentile for motor performance ability over time.

6.16.3 Motor change in the Amber group (mDCD)

Two children were lost to follow up, but the overall picture for the remaining five was variability or change in motor performance ability over time. The entire group improved their motor performance (≥10 points MABC2 total score). Furthermore, the entire group had changed motor category by T3. All scored within the typically developing range and moved from Amber to the Green group (from 6-16th percentile to ≥25th percentile). This group comprised 40%

girls and it is possible that they behaved differently to boys overtime. However, with such small numbers it was difficult to reach a safe conclusion. Detailed analysis of individual cases gave more insight into possible causes and will be discussed later.

6.16.4 Motor change in the Green group (TDC)

Two children from this group did not attend for data collection at T3 and so their scores at T2 were used. Just over half (53%) of this group stayed the same over time (MABC2 total score difference ≤10 points) and equal numbers deteriorated (23.5%), or improved (23.5%). Four children deteriorated over time, of which three changed motor category to Amber by T3.

It was therefore evident that the three groups behaved differently in terms of their motor performance ability over time.

Summary

Data from children in the study with at least two data points (n=31) was analysed. 35.5% of the sample of children improved their motor performance ability between data point one and data point three, 51.6% stayed the same and 12.9% deteriorated. However, the group behaviour appeared to differ between groups. The most stable groups appeared to be the Red (sDCD), followed by the Green group (TDC). The children in the Red group all remained in the lowest 5th percentile of motor ability over time and nearly 78% had no change or change smaller than the SDC of 10 points. None of the Red group deteriorated. The Green group had a more even distribution of change, with just over half (53%) remained stable and equal numbers either deteriorated or improved (23.5%) over time. Consequently, there appeared to be differing degrees of variability in change in motor performance across the sample. The greatest fluctuation appeared in the 6-16th percentile MABC2 range Amber group (mDCD), which resulted in all of the members improving and changing group category over time to join the Green group (≥25th percentile MABC2). By T3 all members of the Amber group had reached the level of typically developing motor performance ability. However, in addition two children from the Green

group deteriorated over time and moved to the Amber group by T3. Therefore, there appeared to be an overlap in motor characteristics between a few children in the lower end of motor ability (≤37th percentile MABC2) in the Green group and all of the children in the Amber group.

The following section explores some of the variables across the groups to investigate how they may have impacted motor progression.

First the distribution of children with associated characteristics across the groups was explored.

6.17 Analysis of the distribution of associated characteristics across groups

Nearly half of the entire sample of children had associated characteristics (47%). This was a higher than expected prevalence and may have resulted from recruiting the majority of the sample of families from children who attended a school with an ASD unit attached. However, the Red group had a greater proportion of children (90%) with associated characteristics and all of those children had two or more associated characteristics. Both the Amber and Green groups also had members with associated characteristics, (40%) and (29.4%) respectively, but the majority only had one associated characteristic (AC). Only one child, who scored in the Green group at baseline, had two or more AC, yet he was exceptional and changed group twice over time. Table 6.21 shows the distribution of children with associated characteristics across the groups over time.

Table 6.21 Analysis of number of children with AC per group over time

	Red	Red +AC	Amber	Amber +AC	Green	Green +AC	Total
T1	1	9	5	2	12	5	**34**
T2	1	10	2	1	13	4	**31**
T3	1	8	1	2	12	5	**29**

However, as previously mentioned, the three groups appeared to have different patterns of progress depending upon the degree of motor impairment at baseline. Table 6.20 shows the number of children who displayed an improvement in motor performance ability greater than or equal to the smallest detectable change (SDC) of 10 points total score of MABC2. Table 6.22 shows the numbers of children in each category and those with associated characteristics are shown in brackets.

6.17.1 Percentage of children with associated characteristics with motor stability or change

Table 6.22 indicates that the children with AC were represented in all categories of progression.

The children with associated characteristics represented 45.5% of the children who improved motor performance ability over time. They represented 56.25% of the children who had no change in motor performance ability over time and represented 50% of the children who deteriorated their motor performance ability over time. However, the numbers involved are small and should be interpreted with caution, yet they would appear to be distributed across all categories of motor ability, whether they improved or remained stable. This would appear to suggest that associated characteristics per se were not the most influential factor in motor progression over time.

Table 6.22 Number of children per group changing (SDC +/- 10 points total MABC2 score) or remaining stable at T3

Group category at baseline	Improved ≥SDC	Same	Deteriorated ≤SDC
Red N=9 **<5th MABC2**	N=2 (With AC=2)	N=7 (With AC =6)	N=0
Amber N=5 **6-16th MABC2**	N=5 (With AC=2)	N=0	N=0
Green N=15 **>25th MABC2**	N=4 (With AC=1)	N=9 (With AC=3)	N=2 (With AC=1)
Total N=29 at T3	**N=11** (With AC=5 or 45.5%)	**N=16** (With AC=9 or 56.25%)	**N=2** (With AC=1 or 50%)

6.18 Analysis of group membership over time

Previous researchers, for example Cantell, Smyth & Ahonen (2003) and Sugden and Chambers (2007) had identified that some children with DCD improve motor performance to typical level over time. So an analysis to ascertain if the children in this sample remained in the same group over time was undertaken. This helped to determine if there was differential progression of motor ability between the groups of children with the different severity of motor impairment (i.e. severity of DCD) at baseline. The analysis of the Red, Amber and Green group membership over time, revealed some interesting information.

The children with severe motor difficulties, who were allocated to the Red group (n=10) at baseline measurement (T1), O% changed groups over time (T1 to T3). One child was lost to follow up, but of those remaining in the study all remained in the Red group over time. This was in direct contrast to the children

with moderate motor difficulties, who were allocated to the Amber group (n=7) at baseline measurement (T1), none remained in the same group over time. Two children were lost to follow up but 100% of the remaining children changed groups over time (T1 to T3).

The children with motor performance ability in the typical range, who were allocated to the Green group (n=17) at baseline measurement (T1), only three changed group over time to T3 (17.6%). The rest remained in the green group over time.

6.18.1 Diagrammatic representation of motor performance ability change over three time points by each group

The Red group (sDCD) showed little variability and even though some children improved their performance over time they still all (n=9) remained in the Red group. This group contained only boys and all but one had two or more associated characteristics. These findings suggested a pattern of stability in motor characteristics of the Red group over time and is represented in Fig. 6.27

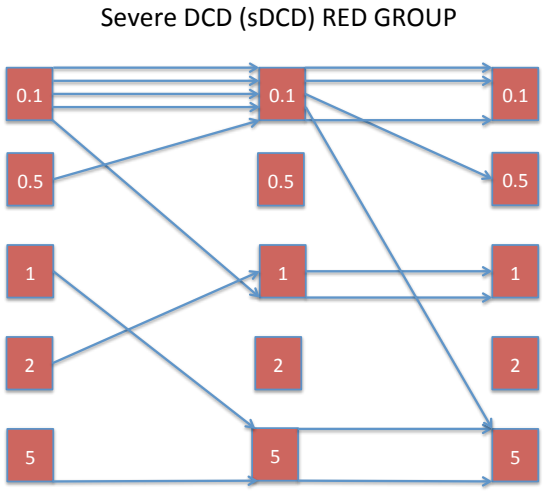


Figure 6-27 Representation of group membership of the children from the Red group over T1, T2 & T3

The Amber group (mDCD) on the other hand demonstrated large variability and many children changed group. All who started in the Amber group had changed to Green group by T3. Three children with associated characteristics started in the Green group but fluctuated greatly and changed groups over time, finishing in the Amber group. One child even fluctuated more wildly and started in Green group but changed to Red and finished in the Amber group. This is represented in Fig. 6.28. This group also contained three girls, two who improved after the first data point and then remained in the Green group over time. Both girls had very poor ball skills, which may have reflected limited opportunity and low expectations placed on girls for these skills. The other girl however was a keen footballer but unfortunately was lost to follow up.

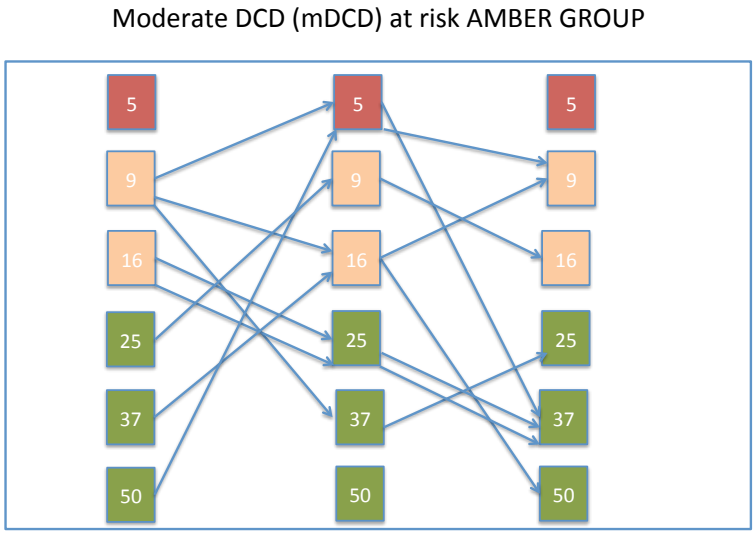


Figure 6-28 Representation of group membership for teh children in the Amber group over time T1, T2 & T3

The Green group (TDC) showed variability in their motor performance ability over time, with some improving, some deteriorating and some remaining stable. However, all but one of the typically developing children (i.e. those without associated characteristics) did not change group over time, all remained in the Green group. The same experienced OT tested all the same children over time and the test retest reliability of the MABC2 is quoted as reasonable (Brown & Lalor, 2009) with Pearson Product Moment Coefficients ranging from 0.73 to 0.84 (Henderson et al., 2007), it can therefore be assumed that the test results

are a reliable representation of the children's performance. This indicated that some fluctuation in motor performance ability over time in typically developing children is to be expected. It also highlights the differences in patterns of change over time between the other groups. Fig. 6.29 represents the Green group over time.

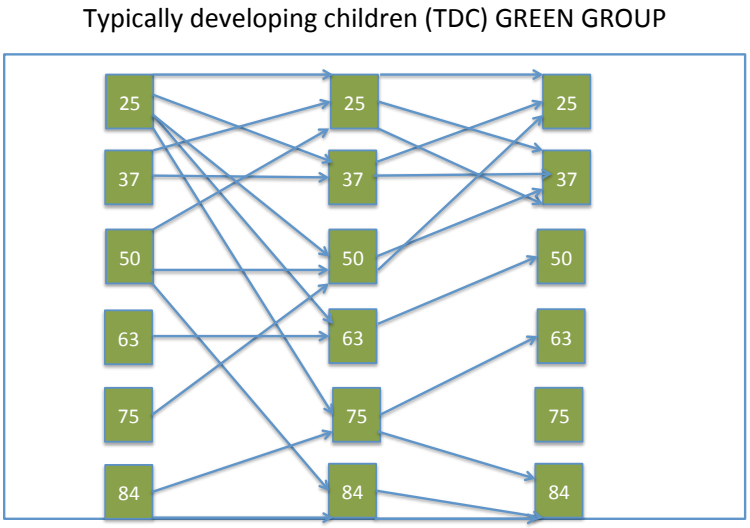


Figure 6-29 Representation fo group membership for the children from the Green group over time, T1, T2 &T3

The distinctive patterns in the different group's motor behaviour over time can be summarized as follows:

Motor change over time

GROUP	Variability	Stability
RED Severe DCD (sDCD)	Small variability	Some stability
AMBER At risk Moderate DCD (mDCD)	Largest variability	No stability
GREEN typically developing (TDC)	Some variability but no large changes	Some stability

Figure 6-30 Summary of group's pattern of motor performance change over time

Thus, children with different severity of motor impairment at baseline (Red, Amber & Green groups) appeared to show differences in the motor progression over time. This was explored further by statistical analysis using to determine if the differences reached statistical significance between the groups.

However, there was a certain amount of intra-group variation within each group. Therefore, plotting the individual trajectories of the children from each group depicts this well.

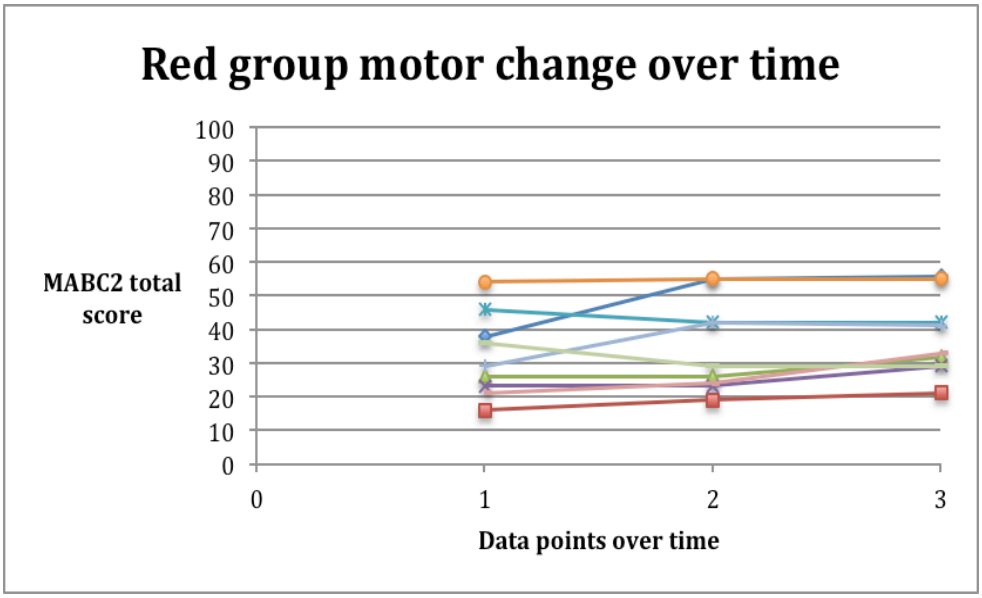


Figure 6-31 Red group motor change over time

Although there was only minimal variation within the red group, one child stands out. The child depicted on the top line in Fig.6.31, was the only child without ASD and had the most consistent scores over time. However, all children in this group remained at or below 5th percentile MABC2 over time.

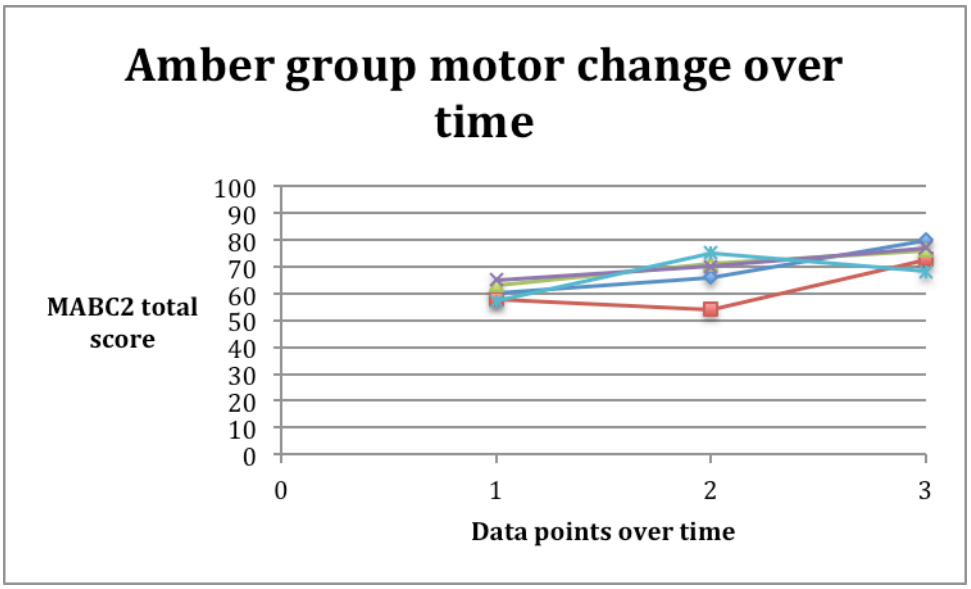


Figure 6-32 Amber group motor change over time

The child represented as the red line in Fig.6.32 had ASD and had the most inconsistent scores over time, but all attained at or above 25th percentile on MABC2 by data point 3.

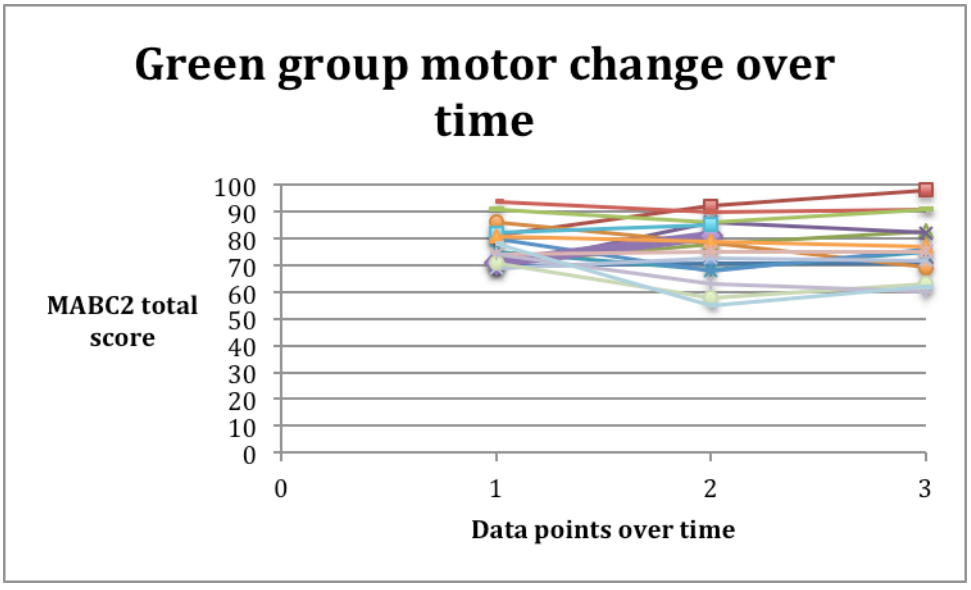


Figure 6-33 Green group motor change over time

The child represented by the lowest blue line in Fig.6.33 had ASD/ADHD, showed the largest variability over time and finished in the impaired range by data point 3.

6.19 Repeated measures ANOVA for group difference in motor progression

Statistical significance was investigated with repeated measures analysis of variance ANOVA (SPSS version 22). All missing data were not included and analysis was undertaken on n = 29 and therefore only 15 children in the Green group.

However, representing group change over time was problematic since group membership changed over time. Change was therefore explored by assigning group membership at baseline (T1) and by statistically comparing the results of various dependent variables of those members over time.

For comparison of more than two groups ANOVA for parametric data or Kruskall Wallis for non-parametric data was used. Parametric tests are more powerful tests, providing the assumptions for parametric data are met (such as normal distribution and a sufficient sample size for power). According to previous calculations these assumptions were met and permitted the use of parametric tests. Please refer to the previous chapter.

Change over time was tested with repeated measures on the same subjects. For repeated measure General Linear Model (GLM) a one way repeated ANOVA to detect group difference along a combination of dimensions was used.

Repeated measures one-way ANOVA computes several means when those means have come from the same entities (e.g. same subjects provide data at multiple time points) (Field, 2013), as was the case in this study. If there are three or more repeated measures then there is an assumption of sphericity.

This has to be tested using Mauchly's test, if the value is less than .05 the assumption is violated and adjustments are made using different columns in SPSS output (Field, 2013, p565). The table labelled within- subject effects shows the main results of ANOVA. If assumption of sphericity is violated then use Greenhouse-Geisser and Huyn-Feldt otherwise read sphericity assumed row. Significant results are less than .05 (i.e. a significant difference). Similarly, for contrasts and post hoc tests a significance of less than .05 was used.

Bonferroni post hoc is robust in terms of Type I error rates and power (Field, 2013 p 547). In terms of test power (the Type II error rate) Maxwell (1980) found Tukey's wholly significant difference test (WSD) to be most powerful under conditions of non-sphericity in very small sample sizes (n=8) but this is reduced in larger sample sizes (n=15) (Field, 2013, p547). As the sample size of the Green group was 17, Bonferroni post hoc tests were used. Type I error occurs when we believe that there is a genuine effect in the population when in fact there isn't. Probability of error is .05 (or 5%) known as α level.

Type II error occurs when we believe that there is no effect in the population, when in reality there is. Cohen (1992) suggests that the maximum acceptable probability of Type II error is .2 (or 20%) and is called the β level (Field, 2013 p68). Power is 1- β (1-0.2=0.8) an 80% chance of detecting an effect

Levene's test of equality of error variance equal across groups was violated at data point one. Hochberg's post hoc analysis was applied because of the unequal number of group members and Bonferroni adjustment was also used to account for repeated comparisons. Pot hoc multiple comparisons indicated significant differences between Red and Amber and Red and Green groups, but not between Amber and Green groups. The most severely impaired children (Red group) progressed differently from both the moderately impaired (Amber) and the typically developing (Green) groups. The results are now presented comparing the groups on each test component.

A comparison of MABC2 total scores over time

The repeated measures of MABC2 total scores (T1 to T3) were compared to determine if there were statistically significant differences between the three groups. A one-way between groups (Red sDCD, Amber mDCD, Green TDC), repeated measures (time 1, time 2, time 3) analysis of variance (ANOVA) was employed to examine the dependent variable of MABC2 total score. Box's test of equality of covariance was not significant, signalling equality across all groups. However, Mauchley's test indicated that the assumption for sphericity had been violated [$\chi 2$ (2) = 6.67, p= .036], therefore Greenhouse-Geisser corrected tests are reported

Within subject effects:

The repeated measures ANOVA with Greenhouse-Geisser correction determined that mean MABC2 total scores differed significantly at data collection times (T1, T2 & T3), [F (1.620, 42.133 =6.849, p=.005, η2 =.209] observed power=.885

This indicated that change in motor ability performance had taken place over the two year time period.

Furthermore the group by time interaction was also significant [F (3.241, 42.133) = 3.772, p= .015, η2 =.225] observed power =.797.

This indicated that there was a group effect.

Between subject effects:

There appeared be a difference between the groups in the way they progressed in motor ability over time. The repeated measures ANOVA determined that the groups differed significantly [F (2,26) = 54.905, p≤ .001, η2=.809] observed power 1.0

Pairwise comparisons using Bonferroni corrections showed that Red (sDCD) group progressed significantly worse than both the Amber (mDCD) group, p

≤.001 and the Green (TDC) group, p ≤.001. However, the Amber (mDCD) group did not differ significantly from the Green (TDC) group over time, p= .088.

Descriptive Statistics

	group	Mean	Std. Deviation	N
MABC2total1	sDCD	32.4444	12.12550	9
	mDCD	60.6000	3.36155	5
	TDC	77.6000	7.89937	15
	Total	60.6552	22.01019	29
MABC2total2	sDCD	34.6667	14.18626	9
	mDCD	67.2000	8.04363	5
	TDC	74.6667	11.14621	15
	Total	60.9655	21.41675	29
MABC2total3	sDCD	37.5556	11.98031	9
	mDCD	74.8000	4.54973	5
	TDC	76.2667	11.02897	15
	Total	64.0000	20.76054	29

Figure 6-34 group mean and SD of MABC2 tottal score over time

Summary

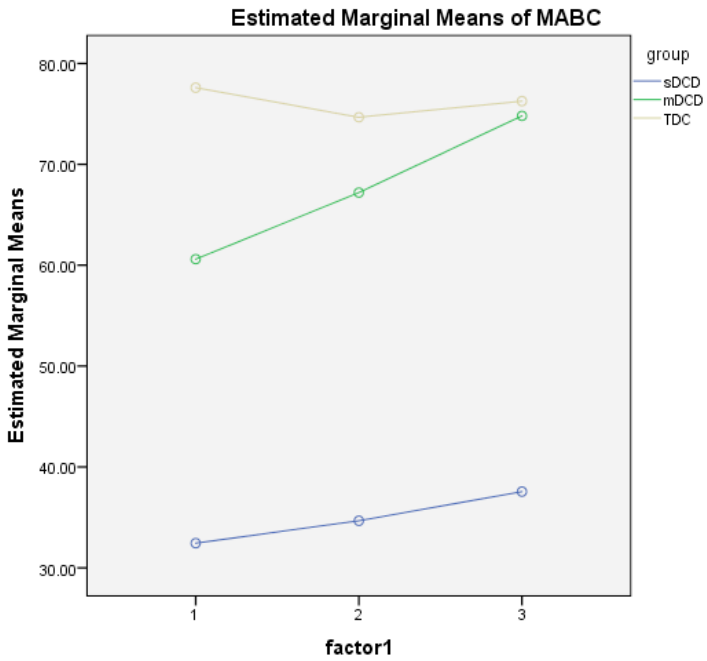
The results indicated that there were significant differences between the groups MABC2 total scores results over time, indicating that the groups had progressed differently. The Red group differed significantly to both the Amber and Green groups. The significance of these results show that the MABC2 total score change over time was significantly affected by severity of motor impairment at baseline. That is, children with the lowest motor ability, classified in the Red group (sDCD) at baseline, progressed significantly differently to children with moderate motor difficulty, classified in the Amber (mDCD) group at baseline and also significantly differently to typically developing children, classified in the

Green (TDC) group at baseline. The mean MABC2 scores (see Fig. 6.34) were consistently the lowest for the Red group over time (T3 mean= 37.4, SD=12.0). Therefore the Red group (≤5th percentile on MABC2 at baseline) was consistently shown to have the greatest degree of motor difficulty and this remained over time.

Although the children with moderate motor difficulty (classified Amber group) appeared to progress differently from the typically developing children (Green group), the difference did not reach statistical difference. This was not surprising since all of the children in the Amber group, which remained in the study, attained performance in the typical range as time progressed to T3. The mean total MABC2 score at T3 for the Amber group (T3 mean=74.8, SD=4.5) was similar to that of the Green group (T3 mean=76.3 SD=11.0).

The progression of the three groups is displayed in Fig. 6.35

Figure 6-35 MABC2 total score over 3 data points (T1, T2, T3) by group



6.20 Repeated measures ANOVA for group difference in CSAPPA progression

In order to determine any consistency or change in the children's self-perception of motor ability, enjoyment and predilection to take part in PA repeated measures of the CSAPPA were taken at the same time as testing with the MABC2. This was to address the research question "How consistent are their self-perceptions of adequacy, enjoyment and predilection to participate in PA or do they change over time?"

The groups were tested for any significant difference between them. A one-way between groups (Red sDCD, Amber mDCD, Green TDC), repeated measures (time 1, time 2, time 3) analysis of variance (ANOVA) was employed to examine the dependent variable of CSAPPA total score. The CSAPPA was a repeated measure of each child's self rated perception of their adequacy, enjoyment and predilection to take part in physical activity measured at the same time as their actual measures of motor performance (measures of MABC2) at T1, T2 and T3.

Box's test of equality of covariance was not significant, signaling equality across all groups. However, Mauchley's test indicated that the assumption for sphericity had been violated [$\chi 2$ (2) = 9.298, p= .010], therefore Greenhouse-Geisser corrected tests are reported.

Within subject effects:

The repeated measures ANOVA with Greenhouse-Geisser correction determined that there was no significant difference between means for CSAPPA scores at TI, T2 and T3 [F (1.51, 37.845)=2.435, p= .114, $\eta 2$=.089] observed power .402

This indicated that the children's self-perception remained relatively consistent over time.

The group by time interaction was not significant [F (3.028, 37.845) = .251, p=.862, η2=.020] observed power .093 This indicated there was no apparent group effect.

Between subject effects:

The repeated measures ANOVA also determined that the groups did not differ significantly [F (2, 25) = .468, p= .632, η2= .036] observed power .118

So there was no significant difference between the groups over time in their self-perception of motor ability, enjoyment and predilection to take part in PA on repeated measures of the CSAPPA. Although interestingly, all three group mean scores were lower at T3 than at T1 indicating lower self-perception over time, although this was not statistically different.

Figure 6-36 CSAPPA group means and SD change over time

Descriptive Statistics

	group	Mean	Std. Deviation	N
CSAPPA1	sDCD	56.1250	13.02127	8
	mDCD	58.6000	11.63185	5
	TDC	61.6000	11.36913	15
	Total	59.5000	11.70470	28
CSAPPA2	sDCD	55.3750	15.87395	8
	mDCD	58.8000	15.83351	5
	TDC	62.7333	10.54559	15
	Total	59.9286	13.07225	28
CSAPPA3	sDCD	53.7500	19.44039	8
	mDCD	53.8000	17.81011	5
	TDC	56.6000	14.75418	15
	Total	55.2857	16.12189	28

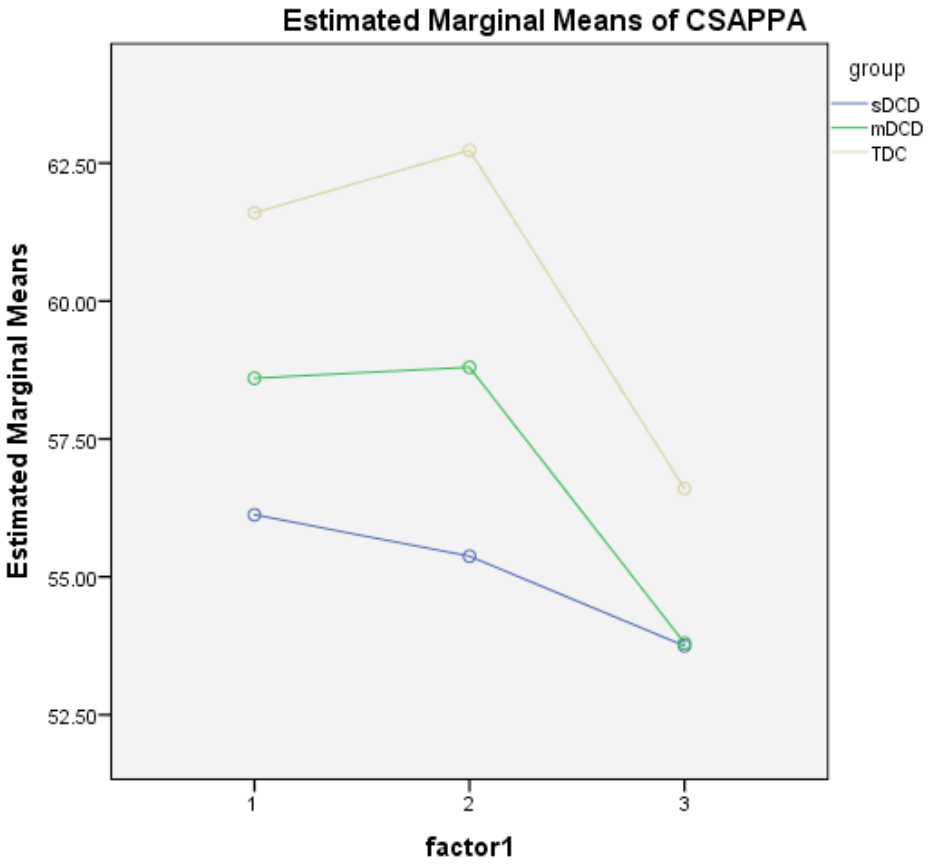
Summary

There was no significant difference between the children with severe motor difficulty Red (sDCD) group, moderate motor difficulty Amber (mDCD) group and the typically developing children Green (TDC) group for the children's self-perception of their adequacy, enjoyment and predilection to take part in physical activity over time. This was somewhat unexpected, since there was a significant group difference in their observed motor performance measures over time. However, as there had been no significant difference in self perception between the groups at baseline, perhaps it was not so surprising that there was no difference in their self perception over time. This was an interesting finding on two counts: The first was that the mean group self-perception remained relatively similar over time. The second was that all the group mean scores deteriorated (i.e. were lower) by T3, please refer to Fig. 6.36. for means and standard deviations and Fig. 6.37 for plots of group means over time.

Another interesting finding was that the mean CSAPPA scores were relatively low at T3 for all groups (Red mean=53.8, SD=19.4, Amber mean=53.8, SD=17.8, Green mean=56.6, SD=14.8). The maximum CSAPPA score is 75 and the CSAPPA cut-off score (to indicate difficulty in physical activity) for girls is 53 and 47 for boys. So we can see that the mean scores for the three groups were all at the lower end.

Although there were significant differences in progression in motor performance between the groups over time, there was no significant difference between the groups for self-perception over time. The results indicate that the group means for self-perception of adequacy, enjoyment and predilection to participate in physical activity over time, in this sample of children, does not appear to relate to their actual motor performance ability measures (MABC2 total score) over time. Other factors may have been more important and so contextual data from case studies will be discussed later.

Figure 6-37 Estimated marginal means of CSAPPA



However, the components of motor performance ability, namely manual dexterity, balance and aiming and catching were also investigated to ascertain if stability or

change in these areas could offer explanation for the CSAPPA scores.

6.21 Repeated measures ANOVA of manual dexterity over time

Manual dexterity is required in all self-care tasks, handwriting and most leisure activities. Impairment in manual dexterity can have a negative impact on independence skills, schoolwork and participation in play. The groups were therefore investigated to determine if there was a statistical difference between the progressions of their manual dexterity performance ability over time. A one-way between groups (sDCD, mDCD, TDC), repeated measures (time 1, time 2,

time 3) analysis of variance (ANOVA) was employed to examine the dependent variable of MABC2 manual dexterity score.

Box's test of equality of covariance was significant, signalling inequality across all groups. However, Mauchley's test was not significant and indicated that the assumption for sphericity could be assumed.

Within subject effects:

The repeated measures ANOVA determined that there was a significant difference between means for manual dexterity scores at TI, T2 and T3 [F (2, 52)=5.523, p= .007, η2=.175] observed power .832 This indicated that there had been a significant difference in manual dexterity over time.

The group by time interaction was also significant [F (4, 52) = 5.089, p= .002, η2= .281] observed power .950 indicating a group difference over time.

Between subject effects:

There was a significant difference between the groups for manual dexterity over time. The repeated measures ANOVA determined that the groups differed significantly [F (2,26) = 56.608, p ≤ .001, η2= .813] observed power 1.0

Pairwise comparisons showed that children with the lowest motor ability (classified as Red (sDCD) group) progressed significantly worse than both the children with moderate motor difficulty (classified as Amber (mDCD) group), p ≤ .001 and significantly worse than typically developing children (classified the Green (TDC) group), p ≤.001 and this was confirmed by post hoc Bonferroni corrections p= <.001. However there was no significant difference between the children with moderate motor difficulty (Amber (mDCD) group) and typically developing children (the Green (TDC) group) over time, p= .103, which was confirmed by post hoc Bonferroni corrections p= .308.

Summary

There were significant differences between the groups in the way their manual dexterity progressed over time confirmed by post hoc tests. Again, children in the lowest motor ability group (Red (sDCD) group) who progressed significantly differently to the children with moderate motor difficulty (Amber group) and the typically developing children (Green (TDC) group). However, the difference between the Amber (moderate) and Green (typical) groups did not reach statistical significance.

Therefore the results showed that manual dexterity change over time was significantly effected by severity of motor impairment at baseline. That is, children in the Red group (sDCD) progressed significantly worse to children in the Amber (mDCD) group and also to children in the Green (TDC) group. The mean manual dexterity scores (see Fig. 6.39) were consistently the lowest for the Red group over time (T3 mean= 10.7, SD=3.0), so consistently had the greatest degree of difficulty in manual dexterity over time.

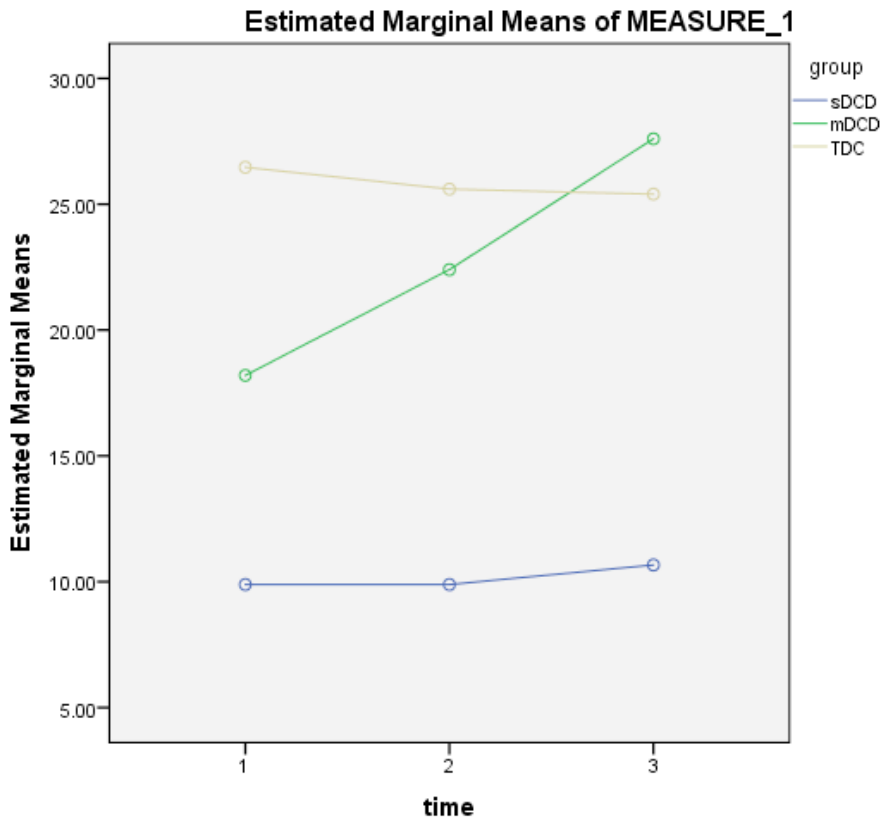
Although the children with moderate motor difficulty (Amber group) appeared to start differently from the typically developing children (Green group), there was no statistical difference between these groups for manual dexterity over time. The group mean for manual dexterity at T3 for the Amber group (mean=27.6, SD=3.8) was higher than the group mean of the Green group at T3 (mean=25.4, SD=6.3). See fig. 6.38

Figure 6-38 Group means and SD Manual dexterity over time

Descriptive Statistics

	group	Mean	Std. Deviation	N
MD1	sDCD	9.8889	3.40751	9
	mDCD	18.2000	4.60435	5
	TDC	26.4667	3.71996	15
	Total	19.8966	8.31240	29
MD2	sDCD	9.8889	4.16667	9
	mDCD	22.4000	4.21900	5
	TDC	25.6000	4.17133	15
	Total	20.1724	8.17692	29
MD3	sDCD	10.6667	3.00000	9
	mDCD	27.6000	3.78153	5
	TDC	25.4000	6.26555	15
	Total	21.2069	8.75614	29

Figure 6-39 Plot of progression of manual dexterity over time



6.22 Repeated measures ANOVA of balance over time

Goal directed movement virtually always requires postural adjustment and a major goal of postural adjustment is to keep balance (Hadders-Algra, 2008). Therefore, any physical play, in which children normally engage, will require a level of balance. Difficulty with balance can be a major barrier to physical activity for children with motor difficulty. Therefore, differences between the groups in the way children progress with balance could have implications for engagement in PA.

A one-way between groups (Red sDCD, Amber mDCD, Green TDC), repeated measures (time 1, time 2, time 3) analysis of variance (ANOVA) was employed to examine the dependent variable of MABC2 balance score. Box's test of equality of covariance was not significant, signalling equality across all groups. In addition, Mauchley's test was not significant and indicated that the assumption for sphericity could be assumed.

Within subject effects:

The repeated measures ANOVA determined that there was no significant difference between means for balance scores at TI, T2 and T3 [F (1, 26)=.804, p=.378, η2=.030] observed power .139

The group by time interaction was also not significant [F (2, 26) =1.182, p= .323, η2= .083] observed power .236

Between subject effects:

There were however, differences between the groups. The repeated measures ANOVA determined that the groups differed significantly [F (2,26) = 41.041, p ≤ .001, η2= .759] observed power 1.0

Pairwise comparisons showed that, once again, the children with the severe motor impairment (Red (sDCD) group) progressed significantly worse than both the children with moderate motor difficulty (Amber (mDCD) group), p ≤ .001 and

the typically developing children (Green (TDC) group), p ≤ .001 and this was confirmed by post hoc Bonferroni corrections p ≤ .001. However, there was no difference between the children with moderate motor difficulty (Amber (mDCD) group) and the typically developing children (Green (TDC) group) over time, p= .597 and was confirmed by post hoc Bonferroni corrections p=1.0.

Figure 6-40 Group means and SD of Balance over time

Descriptive Statistics

	group	Mean	Std. Deviation	N
B1	sDCD	13.44444	6.023104	9
	mDCD	29.00000	5.244044	5
	TDC	33.00000	3.760699	15
	Total	26.24138	9.991622	29
B2	sDCD	13.6667	8.81760	9
	mDCD	30.2000	6.41872	5
	TDC	30.9333	5.04928	15
	Total	25.4483	10.27683	29
B3	sDCD	15.0000	8.97218	9
	mDCD	32.4000	2.19089	5
	TDC	31.6667	4.85014	15
	Total	26.6207	9.92261	29

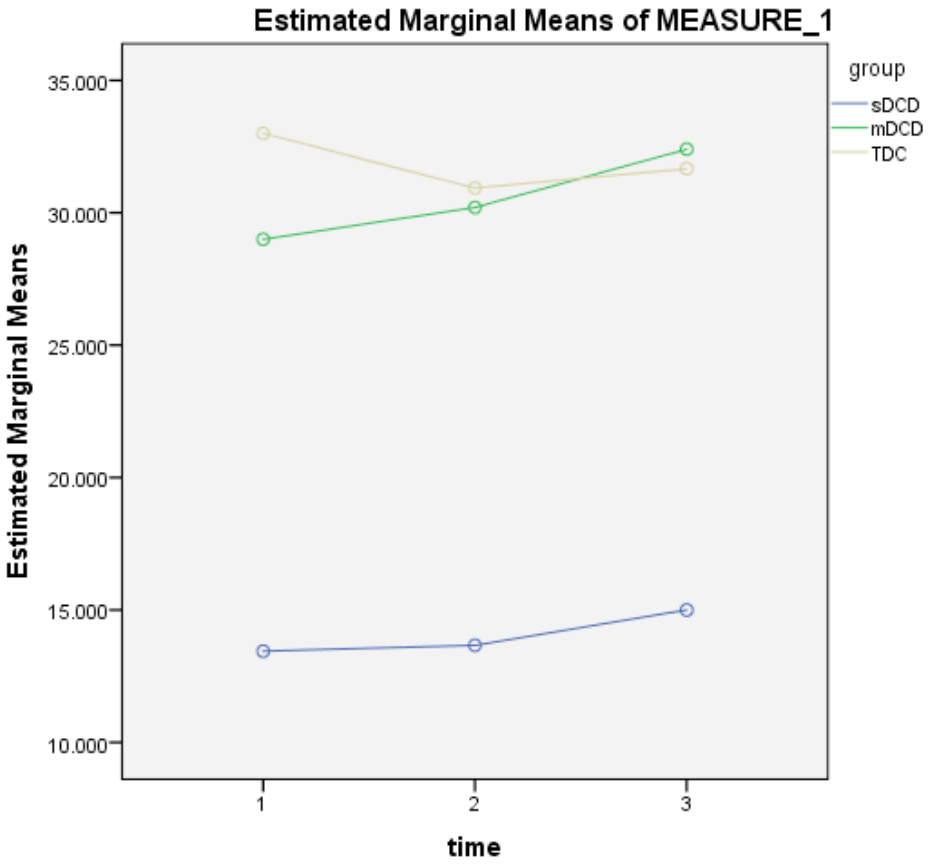
Summary

The results indicated that balance change over time was significantly affected by severity of motor impairment at baseline, as post hoc tests showed significant differences between groups for balance over time. There was a significant difference between the Red (severe) group and the Amber (moderate) group and also between the Red (severe) and the Green (typical) group, but not between the Amber (moderate) group and Green (typical) group.

Children in the Red group (sDCD) progressed significantly worse in balance than children in the Amber (mDCD) group and also to children in the Green

(TDC) group. The mean balance scores (see Fig. 6.41) were consistently the lowest for the Red group over time (T3 mean = 15.0, SD=9.0). Although the children in the Amber group appeared to progress differently from the Green group, the difference did not reach statistical difference. The group mean for balance at T3 for the Amber group (mean=32.4, SD=2.2) was higher than the group mean of the Green group at T3 (mean=31.7, SD=4.9). See Fig. 6.40

Figure 6-41 Plot of group progression of Balance over time



6.23 Repeated measures ANOVA of aiming and catching over time

Skills in aiming and catching are required for many playground games and are fundamental skills for primary school age children. By secondary school age these skills are usually refined and enable children to participate in racquet

sports and team sports. Impairment in these skills can have a profound impact on leisure pursuits and the ability to enjoy and participate team sports. An investigation of any statistical difference between the groups for the progression of aiming and catching was important. A one-way between groups (sDCD, mDCD, TDC), repeated measures (time 1, time 2, time 3) analysis of variance (ANOVA) was employed to examine the dependent variable of MABC2 aiming and catching score. Box's test of equality of covariance was not significant, signaling equality across all groups. Mauchley's test was also not significant and indicated that the assumption for sphericity could be assumed [χ^2 (2) = 2.249, p= .325].

Figure 6-42 Aiming and catching means & SD over time

Descriptive Statistics

	group	Mean	Std. Deviation	N
AC1	sDCD	10.2222	2.90593	9
	mDCD	13.8000	4.26615	5
	TDC	18.1333	4.53347	15
	Total	14.9310	5.30452	29
AC2	sDCD	11.1111	3.10018	9
	mDCD	12.6000	2.07364	5
	TDC	18.1333	5.93857	15
	Total	15.0000	5.66947	29
AC3	sDCD	11.8889	2.97676	9
	mDCD	14.8000	5.58570	5
	TDC	18.2000	4.88730	15
	Total	15.6552	5.20491	29

Within subject effects:

The repeated measures ANOVA determined that there was no significant difference between means for aiming and catching scores at TI, T2 and T3 [F (2,52)= .947, p= .395, η2= .035] observed power= .205.

The group by time interaction was also not significant [F (4,52) = .492, p= .742, η2= .036] observed power .158

Between subject effects:

There was, however, a significant difference between the groups in the way they progressed in aiming and catching over time. The repeated measures ANOVA determined that the groups differed significantly [F (2,26) = 10.109, p = .001, η2= .437] observed power .974.

Pairwise comparisons showed that once again it was the children with the most severe motor difficulty (Red (sDCD) group) that progressed significantly worse than the typically developing children (Green (TDC) group), p ≤.001, confirmed by post hoc Bonferroni corrections p ≤.001. However, there was no significant difference between the children with the severe motor difficulty (Red group) and the children with only moderate motor difficulty (Amber group) for aiming and catching, p= .223, supported by Bonferroni corrections, p= .669. However, pairwise comparisons revealed a difference between the children with moderate motor difficulty (Amber (mDCD) group) and typically developing children (the Green (TDC) group) over time, p= .034. However, this was not supported by post hoc Bonferroni corrections p= .101

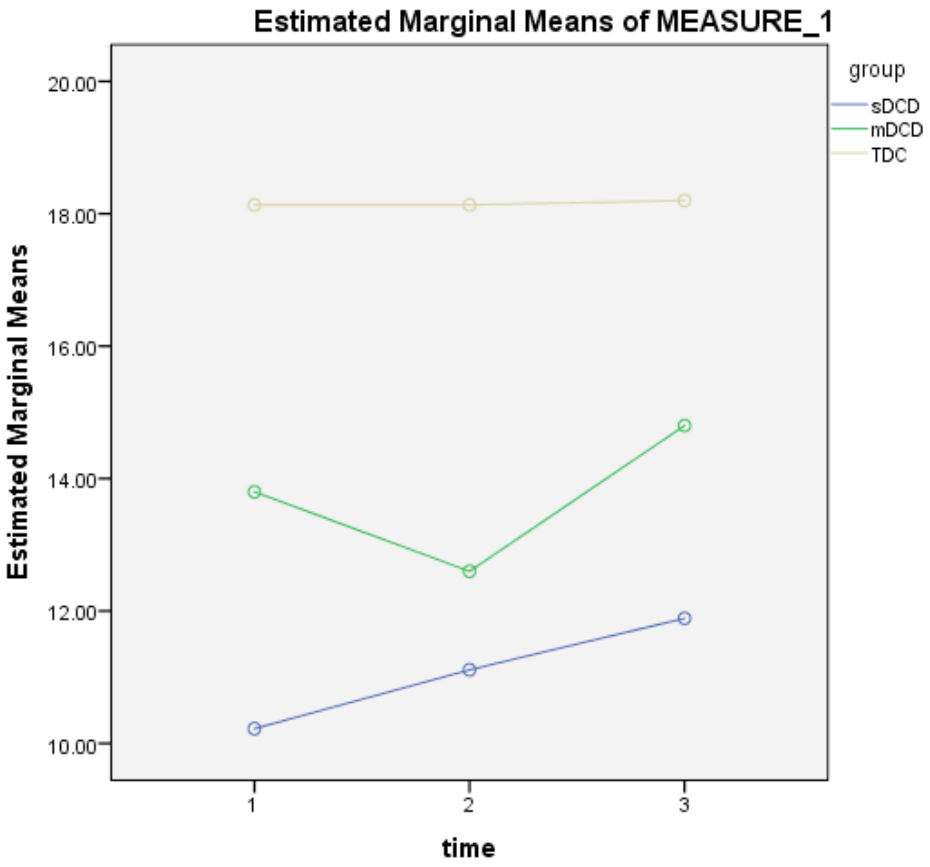


Figure 6-43 Plot of Aiming and catching group means over time

Summary

The results indicated that the progression in aiming and catching over time was also significantly affected by severity of motor impairment at baseline. Post hoc tests showed significant differences between the groups for aiming and catching over time. There was a significant difference between the children with the most severe motor difficulty (Red (sDCD) group) and typically developing children (Green (TDC) group), but not between the Red group and the children with moderate motor difficulty (Amber group), or between the Amber and Green (TDC) groups.

Children with the most severe motor difficulty (Red (sDCD) group) progressed significantly worse than typically developing children (Green (TDC) group). The mean aiming and catching scores (see Fig. 6.42) were consistently the lowest for the Red group over time (T3 mean = 11.9, SD=3.0). Although the children with moderate motor difficulty (Amber group) appeared to progress differently

from typically developing children (Green group), the differences did not reach statistical difference on post hoc testing (p= .101). Incidentally, there had been no statistical difference between the Amber and Green groups at baseline for aiming and catching either. Interestingly, there was no statistical difference between the children with severe motor difficulty (Red) and the children with moderate motor difficulty (Amber) groups for aiming and catching over time (p= .669) either. This suggests that the children in the Amber group still experienced difficulty with aiming and catching. The group mean for aiming and catching at T3 for the Amber group was (mean=14.8, SD=5.6) and for the Green group at T3 was (mean=18.2, SD=4.9).

6.24 Repeated measures ANCOVA MABC2 total score Covariate for IQ composite

Since there had been a significant difference in IQ between the groups at baseline, a one-way between groups (sDCD, mDCD, TDC), repeated measures (time 1, time 2, time 3) analysis of covariance (ANCOVA) was employed to examine the dependent variable of MABC2 total score, using composite IQ score as covariant. Box's test of equality of covariance was not significant, signaling equality across all groups. Mauchley's test was significant and indicated that the assumption for sphericity had been violated [$\chi 2$ (2) = 6.284, p= .043]; therefore Greenhouse- Geisser corrected tests are reported.

Within subject effects:

The repeated measures ANCOVA with Greenhouse-Geisser correction determined that the group by time mean MABC2 total scores differed significantly [F (3.25,40.6 =3.505, p= .021, η2 =. 219] observed power= .763.

Between subject effects:

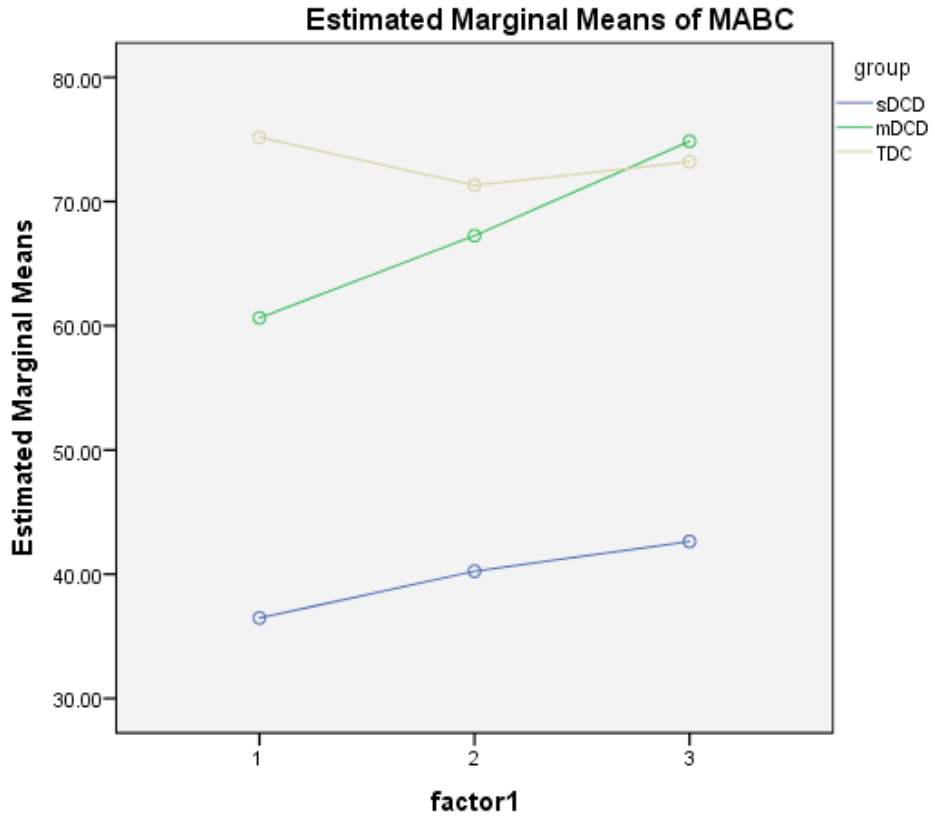
The results showed that there was still a significant difference between the groups in motor performance ability over time. The repeated measures

ACNOVA determined that the groups differed significantly [F (2,25) = 19.887, p ≤ .001, η2= .614] observed power 1.0

Pairwise comparisons using Bonferroni corrections showed that Red (sDCD) group progressed significantly worse than both the Amber (mDCD) group, p ≤ .001 and the Green (TDC) group, p ≤ .001. However, the Amber (mDCD) group did not differ significantly from the Green (TDC) group over time, p= .256.

The results from the ANCOVA were similar to those of the ANOVA, indicating that the difference in IQ between the groups had not changed the outcome; that there was a significant difference between the children with SDCD and typically developing children, but that there was not a significant difference between the children with moderate motor difficulty and typically developing children over time.

Figure 6-44 ANCOVA MABC2 covariate for IQ



Covariates appearing in the model are evaluated at the following values: IQcomp = 97.3793

6.25 Summary of results part II

Summaries of the group results of each ANOVA, with Bonferroni corrections are quoted below. These compare the group means for total motor change and each component of the motor change over time.

ANOVA MABC2 total score over time

Red Amber p≤.001

Red GREEN p≤.001

AmberGreen NS p= .088

ANOVA Manual Dexterity over time

Red Amber p≤.001

Red GREEN p≤.001

AmberGreen NS p= .308

ANOVA Balance over time

Red Amber p≤.001

Red GREEN p≤.001

AmberGreen NS p= 1.0

ANOVA Aiming & Catching over time

Red Amber NS p= .669

Red GREEN p≤.001

AmberGreen NS p= .101

ANCOVA for composite IQ MABC2 total score over time

Red Amber p≤.001

Red GREEN p≤.001

AmberGreen NS p= .256

In addition the ANOVA of self perception over time

CSAPPA overtime

All groups NS p= .632

The children in the Red group (sDCD), who started with MABC2 total score ≤5th percentile remained significantly different to the children who started in the Green group (TDC) >25th percentile in all motor domains over time. Furthermore, the Red group remained significantly different to the children who started in the Amber group (mDCD) 6-16th percentile on MABC2, for total MABC2 score, manual dexterity and balance, but not for aiming and catching over time.

However, the Amber group did not significantly different from the Green group on any of the motor domains over time.

There was a significant different between the groups in IQ and so an ANCOVA with covariance of composite IQ score was run and revealed that the difference in motor ability over time was significant between the Red and Green groups and the Red and Amber groups, but not between the Amber and Green groups over time.

It therefore appeared that the children who met criteria for severe DCD (≤5th percentile MABC2) were not only significantly different from typically developing children at baseline in their motor and associated characteristics, but also significantly differed from typically developing children in their change in motor

ability over the two year period of observation. They therefore appear to be a very distinct group in terms of their motor progression, IQ and associated characteristics. However, they did not differ significantly from typically developing children or from the children with moderate motor difficulties in their self-perception either at baseline or over time.

The children who started in the 6-16th percentile of MABC2 with moderate difficulty in motor ability (Amber group) differed significantly from the group with severe DCD (Red group) and the typically developing group (Green group) at baseline. The Amber group also differed from the severe group over time in all domains except aiming and catching.

However, despite differing from typically developing children at baseline, the Amber group did not differ from them significantly in any motor domain over time. This is because all the children in the Amber group improved their motor ability over time and achieved typically developing scores by T3. That is, they were indistinguishable from the typically developing group over time and apparently caught up.

In answer to the research question “How stable are the motor characteristics or do they change over time?” These data suggest that in this study the group of children with severe motor impairment differed both from the group of children with moderate motor difficulties and from the group of typically developing children at baseline. Furthermore, they progressed differently in their motor performance ability over time to both the typically developing children and the children with moderate motor difficulty. Their motor characteristics appeared to remain relatively stable over time, whereas the children with moderate motor difficulties changed over time.

In answer to the research question “How consistent are their self perceptions of their adequacy, enjoyment and predilection to take part in PA or do they change over time?” The data suggests that there was no significant difference in the group’s self-perception either at baseline or over time, despite their difference in

motor progression over time. This points to consistency in the group mean children's self-perception over time for all groups.

6.25.1 Correlations to examine possible explanatory relationships

In order to investigate the unexpected Red group CSAPPA results further baseline correlations were undertaken to check for any relationships. It could have been possible that children with lower IQ did not understand the CSAPPA questions, in which case we could expect a significant correlation (i.e. $p<0.05$) between IQ and CSAPPA score at baseline. However, the correlation was non significant. It could also have been possible that younger children did not experience the impact of poor motor control on participation in PA to the extent that older children do. In which case we would expect a significant correlation between age and CSAPPA at baseline. However, the correlation did not reach significance.

Pearson Correlations were run at baseline to examine any significant relationships.

There were no significant correlations (i.e. $p>0.05$) between:

CSAPPA and age ($r= .341$) ($p= .052$)

CSAPPA and IQ ($r= .058$) ($p= .748$)

CSAPPA and MD ($r= .267$) ($p= .134$)

There was a weak significant correlation ($p= .05$) between baseline scores of:

CSAPPA and MABC2 ($r= .358$) ($p= .041$)

CSAPPA and A&C ($r= .346$) ($p= .049$)

CSAPPA and Balance ($r= .365$) ($p= .037$)

However, medium significant correlations ($p= .01$ two tailed) were found between:

DCDQ 07 and age (r= .517) (p= .003)

CSAPPA and DCDQ 07 (r= .553) (p= .001)

However stronger significant correlations (p= .01 two tailed) were found between:

MABC2 and IQ (r= .648) (p< .001)

MABC2 and DCDQ 07 (r= .686) (p< .001)

Non-parametric Spearman's rho and Kendall's tau were also run and the results were the same, except there was a weak significant correlation between age and CSAPPA with Kendall's tau 0. 247 (p= .47)

It was clear that self-perception was not solely dependent upon motor performance ability and in order to understand more a case study approach whereby selected cases were investigated in more detail.

Correlations www.statstutor.ac.uk

Assumes normal distribution, interval or ratio data. If not use Spearman's Rank

Table 6.23 strength of correlation

.00 - .19	Very weak
.20 - .39	Weak
.40 - .59	Medium
.50 - .79	Strong
.80 – 1.0	Very strong

6.26 RESULTS PART III: Impact of characteristics, stability or change

The previous results described the different profiles of children with and without DCD and their stability and change in motor performance ability and self-perception over time. The results from analysis of these data addressed the first three research questions pertaining to the characteristics of children with and without DCD and the stability or change in their motor profiles over time. The children with different severities of motor difficulty progressed differently, yet little was known about whether this had an impact on their experience of participation in physical activity. Part III of the study addressed this with the research question:

How do the characteristics and stability or change in motor ability and self-perceptions impact experiences of participation in physical activity from the child's perspective?

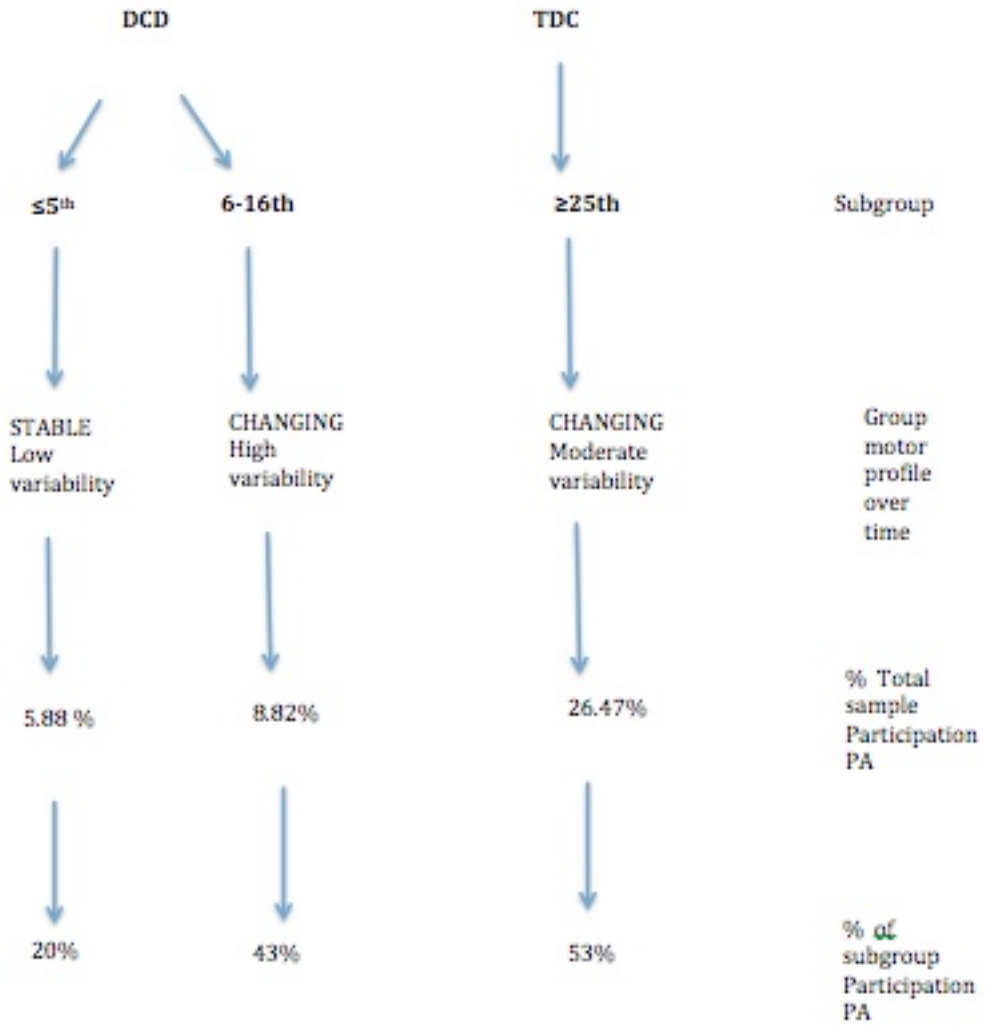
6.27 Group analysis of rates of participation in extra curricular PA

The groups categorized by motor performance ability at baseline testing (T1) not only revealed different characteristics but also different patterns of stability and change in motor performance ability over time. Moreover, analysis revealed that the groups also had different rates of participation in extra curricular physical activity (PA). Please refer to Fig. 6.45. The children in the lowest 5th percentile of motor ability had the lowest participation rate of less than 6% of the sample. Those with moderate motor impairment did not fair much better, only just fewer than 9% of children in 6-16th percentile group participated in extra curricular PA. Whereas 26.5% of children in TDC motor range participated in PA. These results show greater contrast when examined at subgroup level in table 6.24.

Table 6.24 Motor subgroup participation rates in extra curricular PA

≤5th MABC2 (n=10)	6-16th MABC2 (n=7)	≥25th MABC2 (n=17)
2 (20%)	3 (42.86%)	9 (52.9%)

Figure 6-45 Overview of group motor progression and participation in PA



The children with the most severe motor impairment, (≤5th percentile MABC2) possessed distinctive characteristics and progressed very differently to children in the other two groups. They had greater areas of difficulty across domains such as daily activities, IQ and SEN and furthermore, had stable low motor performance ability over time. It is therefore not surprising that they participated much less in extra curricular PA than those with typical motor development and slightly less than those with a moderate motor impairment. However, this places the children at greatest risk by limiting opportunities for active participation and motor practice and could lead to secondary problems associated with inactivity.

The children with moderate motor impairment at baseline testing also had a much lower rate of participation in extra curricular PA than TDC, but surprisingly only slightly greater participation than the severe group, despite their variable motor progression and improvement to that of TDC over time. These children are therefore also at risk of the same secondary problems.

As predicted, the typically developing children, (≥25th percentile MABC2) had the highest rate of participation in PA, as 53% of the group participated in PA. This group was therefore nearly twice more likely to participate in PA than the lowest motor ability group. These results indicated that the children with any motor impairment were at a distinct disadvantage for participation in extra curricular PA.

Summary

The extant literature indicated that participation in PA is dependent upon many factors, including the family context and resources. However, group contextual data from the children and families at baseline testing (T1) indicated that there was no difference in SES and family resources between those with motor impairment and those without. Furthermore, 80% of the sample attended the same school and lived in the same area with access to the same community resources. Moreover, there was no difference between the groups in their self-

perception of adequacy predilection and enjoyment of PA either at baseline or over time. The difference in participation rates appeared to be due to different motor abilities. Children with motor impairment, either moderate or severe in this study had very low participation rates (less than 9% and less than 6% of the whole sample respectively) and are therefore at risk of the secondary consequences of non-participation in PA. However, the TDC group only had 26.5% participation rate, which is relatively low and also a cause for concern.

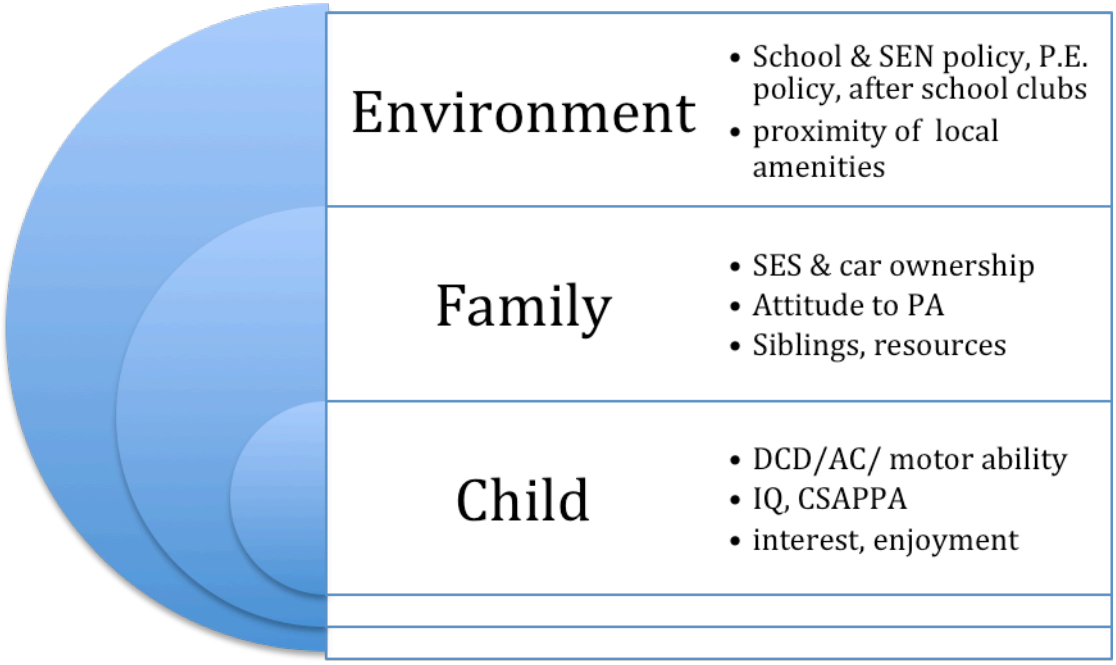
Although group data highlighted differences between the groups, it did not offer explanation for the underlying cause of the differences. On the surface, motor ability appeared to be an important factor, but missed out any complexity in the individual context. Examination of individual data was therefore undertaken by case analysis to explore more fully the different participation rates of the children from each motor group. The case sampling method indicated in chapter five required modification as the stable and changing profiles method outlined was not possible, because all the children in the 6-16th percentile group had changing profiles and changed groups and the entire ≤5th percentile group had stable profiles to remain in the same group. However, measures of IQ, presence of associated characteristics, measures of child self-perception and an account of family and school context were available to augment the group data and provide detailed case analysis.

6.28 Cross case analysis

Where group comparison explored the trends, the differences and similarities in the group averages, it told us nothing about specific individuals and their context. This study design was ecological, which permitted cases to be studied within the context of Bronfenbrenner's Bio ecological framework. A cross case analysis was undertaken to compare both the individual and the contextual characteristics of the children who participated in extra curricular activity in order to explore which factors might be facilitative. Children that were typical and atypical for their group were chosen from each category. It was predicted,

from the extant literature, that the characteristics of the children who participated in PA would demonstrate a high level of motor performance ability, enjoy PA and have a positive self-perception about their ability. Additionally, that the families would rate PA as important, have adequate resources and that the parents would participate frequently in PA. However, the findings revealed some exceptional cases and by comparing these and typical cases some themes and points illustrated areas for future investigation and possible intervention.

Figure 6-46 Bronfenbrenner's bio ecological model used as a framework to explore differences in children's perception of participation in PA



6.28.1 Environment (exosystem and mesosystem levels)

The majority of the sample (80%) attended the same primary school and provided data to consider the context of the children in more detail. All but one of the chosen cases (a girl) attended the same primary school. She was included as a case because she transitioned to secondary school during the study. The primary school was situated in an area of deprivation where 70% of the children received free school meals. The school had an inclusive ethos and ran a number of after school clubs and activities ranging from sedentary

activities such as chess and IT club to active physical activities such as athletics, cricket club and football. The school playground had parallel bars, tyres and stepping-stones as permanent fixtures and the children could also play with hoops and balls in playtime. P.E. lessons were inclusive and all the children were encouraged to participate in sports such as rounders, cricket and field sports. There was a large playing field next to the school and a community leisure centre with swimming pool close by, where the children had school swimming lessons. There was a good bus route between the leisure centre and surrounding areas, however, the roads were very busy and the leisure centre was on the opposite side of a dual carriageway to the school.

6.28.2 Family (microsystem and mesosystem levels)

The family characteristics of the children who did not participate in extra curricular PA were compared with those of the children who participated to investigate any distinguishing features.

Table 6.25 Comparison of contextual characteristics of participating and non-participating children

	Participating children (P) n=14 **(% of P children)**	**Non-participating (NP) children n=20** **(% of NP children)**
Low importance of PA ranked ≤2/4 by parents	N=1 (7.14%)	N=10 (50%)
Low parental participation in PA ≤2 x monthly	N=1 (7.14%)	N=8 (40%)
No car	N=1 (7.14%)	N=9 (45%)
No siblings	N=5 (35.71%)	N=4 (20%)
Unemployed parents	N=1 (7.14%)	N=8 (40%)

6.28.2.1 Summary of the characteristics and context of the children who did not participate in extra curricular PA

The children who did not participate varied widely across motor performance scores and were present in each subgroup. Although in general children with poorer motor performance participated less than typically developing children, motor performance ability did not appear to be the only factor in participation for these children. Economic resources and family attitude appeared to be important factors for children who did not participate in extra curricular PA. Car ownership was low, either no car or just one car per family. Additionally, the number of families with more than one child under 18 was high across the children who did not participate, suggesting that sufficient physical resources may be an important factor in participation in extra curricular PA.

The importance a family attached to PA and how often the parents participated themselves also appeared important, as the parents of the children who participated less generally ranked importance lower and participated less frequently themselves.

6.28.2.2 Summary of the characteristics and context of the children who participated in extra curricular PA

The families of the children who did participate in extra curricular PA all ranked PA high, the parents all participated weekly or twice weekly themselves. All but one family had one or more cars and the majority had two or fewer children under 18 in the family, so that they appeared to have adequate resources.

It appeared that family resources and characteristics were important for all children who participated in PA, but especially for those with motor difficulties (i.e. Red and Amber groups).

6.28.3 Child

The characteristics of stability or change in motor performance (MABC2 scores) and self-perception (CSAPPA scores) were compared by subgroup of category of motor ability at baseline. Typical profiles are shown in Fig. 6.47 & 6.48.

6.28.3.1 Children who participated

Despite their verbal IQ ranging from 79-122, some commonalities emerged across the children who did participate. All the children enjoyed or had predilection to take part in PA at 80% or above, they also rated their adequacy to take part in PA at 70% or above on CSAPPA subtests. All did not change their self-perception over time greater than four points on CSAPPA total score, but change in their motor performance ability over time was not a common factor. So there appeared to be more stability in self-perception across these cases, but not for motor ability.

Figure 6-47 Classic profile of MABC2 & CSAPPA over time for TDC

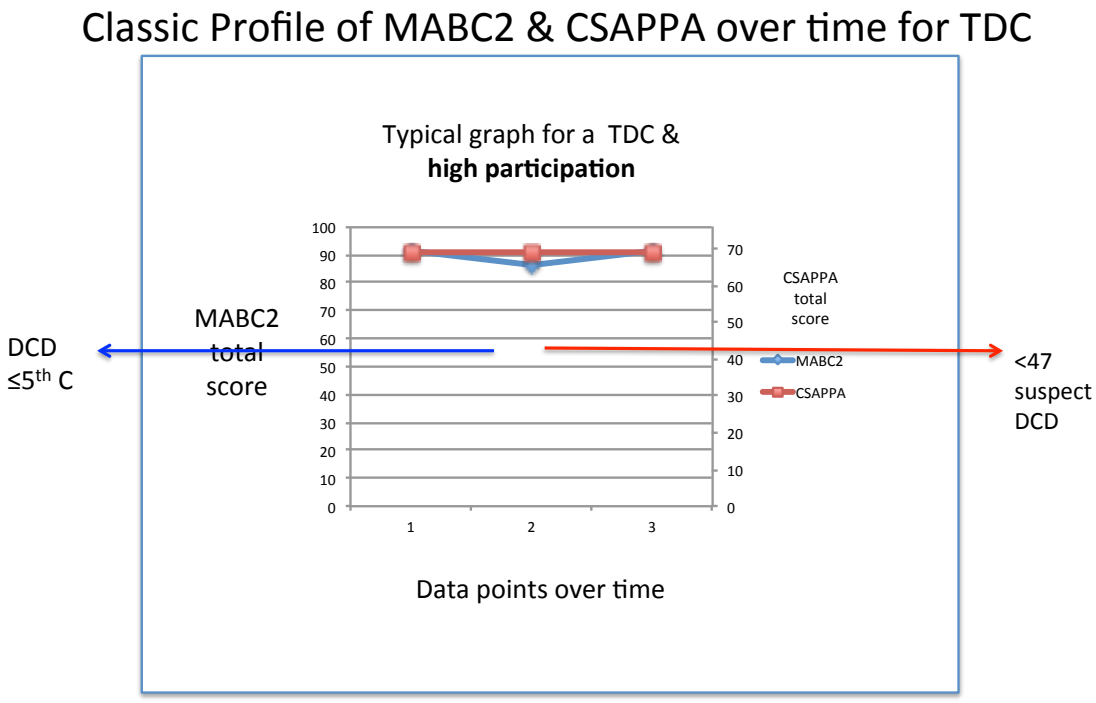
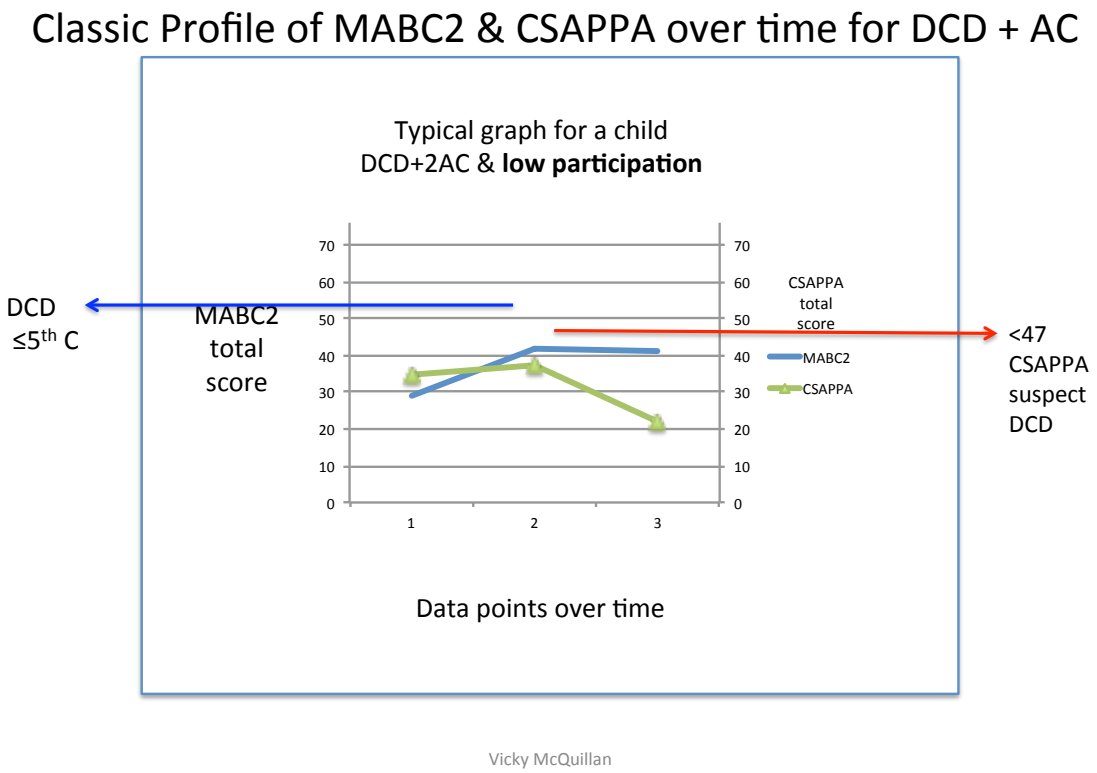


Figure 6-48 Classic profile of MABC2 & CSAPPA over time for DCD+AC



6.28.3.2 Stability and change of motor performance ability and self-perception

Table 6.26 Summary of stability or change for TDC/Green group

Stability or change >10 MABC2	Change in MABC2 total score T3-T1	Change in CSAPPA total score T3-T1
Stable n=9 Deteriorated n=4 Improved n=4	Ranged from -16 to +17	Ranged from -23 to +15

The change in CSAPPA scores did not necessarily follow the same pattern as the change in MABC2 scores over time for the TDC. However, the children with stable motor profiles tended to have more stable self-perception with individual

change in CSAPPA scores ranging from -4 to 0 over time, although group range was large.

Table 6.27 Summary of stability or change for moderate/Amber group

Stability or change >10 MABC2	Change in MABC2 total score T3-T1	Change in CSAPPA total score T3-T1
Stable n=0 Deteriorated n=0 Improved n=5	Ranged from +11 to +20	Ranged from -21 to +11

The change in CSAPPA scores did not appear to have a pattern for the children with moderate motor impairment. Despite the motor scores improving for all five children, the self-perception for three of the children deteriorated over time.

Table 6.28 Summary of stability or change for severe/Red group

Stability or change >10 MABC2	Change in MABC2 total score T3-T1	Change in CSAPPA total score T3-T1
Stable n=7 Deteriorated n=0 Improved n=2	Ranged from -7 to +18	Ranged from -26 to +11

The change in CSAPPA scores appeared more erratic for the children in the severe group. The two children who improved their MABC2 score > 10 points actually both scored lower on their CSAPPA over time.

6.28.3.3 Children who did not participate

The children who did not participate in extra curricular PA had IQ ranging from 55-131 and so IQ did not appear to be an important factor. However, there

were many more (14) children with associated characteristics who did not participate than who participated (two). There was less stability over time in their self-perception, with change in total CSAPPA score ranging from 1-26 points in the children who did not participate. A greater proportion of children with lower motor ability did not participate in extra curricular PA, but they were evident across all motor abilities.

6.28.4 Selected cases

Selected cases from each group are described to examine and compare the patterns of progression and contextual details. Let us first consider the cases examples of the children who did not participate in extra curricular PA and characterise them by the Red, Amber and Green groups.

6.28.4.1 Case 1 Non-participating child Red (≤5th percentile MABC2) group

The non-participating child case in the Red group is typical of the children in this group that did not participate in PA, all of whom had associated characteristics in addition to meeting the criteria for DCD. This 8-year-old boy had a diagnosis of autistic spectrum disorder and also had attention difficulties in addition to DCD. His verbal IQ was 95. He had very low motor performance ability in manual dexterity, aiming and catching and balance (all scores at or below the first percentile). He also had low enjoyment of PA (25%) and low self-perception of his predilection to take part in (58%) and of his adequacy in performance of PA (39%). This pattern was as predicted and it was unsurprising that he did not participate. Of important note is that none of the children in this group changed motor category over time, i.e. their motor performance ability remained stable over time. However, despite his motor performance remaining stable, he did not have stability in his self-perception over time. His enjoyment remained low, but his scores in predilection and adequacy to take part in PA halved over time. He clearly did not enjoy PA and

it appeared that he noticed a gulf between his motor performance and that of his peers over time and became less inclined to participate in PA.

His contextual data sheds a little more light on his case. Despite his parents ranking importance of PA high (3 out of 4) and participating weekly, they did not have a family car and also had another child with DCD and ASD characteristics of primary school age. Thus, finding suitable extra curricular PA and being able to transport the children were two additional barriers for this family.

The Amber cases were more complex and appeared to fall into two categories; those that enjoyed PA and rated their self-perception over 80% yet still did not participate and those that clearly did not enjoy PA. However, some of this group was lost to follow up over time and so data is incomplete. Contextual data may be more important for these children and will be discussed.

6.28.4.2 Case 2 Non-participating child Amber (6-16th percentile MABC2) group

This 8-year-old boy had a verbal IQ of 79. His motor performance ability at baseline measurement put him in the 'at risk' category and he also had behaviour difficulties consistent with oppositional defiance disorder. His manual dexterity score was at 1st percentile, his aiming and catching was at the 50th percentile and his balance was at 25th percentile. This profile should not preclude him from participating in ball games. His self-perception of enjoyment of PA was 92% and his predilection to take part and his adequacy in were both 89%, so he rated himself high across the three categories. However, both his motor ability and his self-perception changed over time. Despite the fact that his motor performance improved to that of typically developing peers and his self-perception improved, he still did not participate in extra curricular PA.

His contextual family data helps illustrate some important factors. There were four children under 18 years old in the family and his father was caring for the children alone. The family owned one car, three of the other children had attention or behaviour difficulties and, due to few economic resources, the

children were entitled to free school meals. In addition the family ranked the importance of PA low and his parents rarely participated in PA. Therefore, the contextual circumstances of this child add additional barriers to participation in extra curricular PA.

6.28.4.3 Case 3 Non-participating child Green (≥25th percentile MABC2) group

The child in the Green group without associated characteristics is typical of other cases in this category. This 8-year-old boy had a verbal IQ was 132 and he was bright and able at school. He rated enjoyment of PA at 75% (most rated lower than 80%) despite rating adequacy at 86% (most rated 80% or above). His overall motor performance was in the typical range. His aiming and catching was at 75th percentile, his balance at 25th and his manual dexterity was at 9th percentile. This sort of profile would not hinder participation in ball games or schoolyard activities. His motor performance improved over time but he did not change motor category over time (i.e. remained in the typically developing range). However, he did change his self-perception over time. Noticeably his adequacy and predilection scores reduced over time and lower enjoyment (75%) also appeared to be an important factor here.

In addition, his contextual data also helped to explain his non-participation. He was one of four children under 18 years old, cared for by his single mother. Importance of PA was ranked low (2 out of 4) and undertaken rarely. There was no family car and limited family finance.

6.28.4.4 Case 4 Non-participating child an exceptional case

This 8-year-old boy had a verbal IQ of 112. He started in the Green group, but his motor performance deteriorated so much that he changed groups. He had associated characteristics, which included autistic features and attention difficulties. He was an atypical case. Despite his high verbal IQ and motor performance in the typical range across all subtests at the starting point, he

rated his self-perception of predilection (33%), adequacy (29%) and enjoyment (42%) very low. His perception changed over time, as did his motor performance, both of which deteriorated over time. He was afraid of ball play and often refused to go into the playground. His very low self-perception was an important factor, but he also had some contextual barriers too. He was an only child living with his single mother. They had no family car and importance of PA was ranked low (2 out of 4).

6.28.4.5 Case 5 Non-participating girl exceptional case

Another exception appeared with a girl who started in the Amber group and despite her motor performance improving over time, her enjoyment and self-perception started high but deteriorated over time. This 10 year-old girl had a verbal IQ of 122 and her manual dexterity and aiming and catching scores were both either at or below the 5th percentile and her balance was at the 75th percentile. She rated her enjoyment of PA at 100% and her predilection to take part and adequacy in PA at 94% and 82% respectively at baseline. Her parents rated PA very high (4 out of 4) and participated weekly themselves. There were two children under 18 years old in the family and they had one car. Her motor performance improved, so that she performed in the typically developing range over time, and moved to the Green group. So despite improving motor performance, adequate family resources and a positive parental attitude towards PA this girl did not participate in extra curricular PA. This pattern also occurred with two other girls of a similar age. Interview data revealed some interesting issues that were important to her and her age and gender may well be overriding factors.

Let us now consider the characteristics of the children who did participate in PA.

It was predicted that the characteristics of children who did participate in extra curricular PA would be a good motor performance, especially in the aiming and catching and balance components of performance, as these skills are required for team games and most sports. Additionally, it was predicted that they would

have high enjoyment and self-perception of predilection to take part in PA and adequacy in performance of PA. However the results showed some unexpected results.

Importantly, children from the Red and Amber lower motor performance ability groups did enjoy PA and participate and have a good self-perception. By examining their family context we are able to understand a little more.

6.28.4.6. Case 6 a participating child from Red (≤5th percentile MABC2) group (DCD plus AC)

This 10-year-old boy had additional associated characteristics of autism and attention difficulties as well as meeting the criteria for DCD. His verbal IQ was 89. His motor performance ability was low (1st percentile for manual dexterity, 2nd percentile for aiming and catching and 5th percentile for balance). However, he rated his enjoyment of PA at 92% and his predilection to take part in PA at 80% and his adequacy at 70%. Both his motor performance ability and his self-perception remained stable over time. Thus, despite his low motor performance ability, which did not change over time, he enjoyed and wanted to participate in PA and rated his performance quite well. Some of his contextual data and interview shed more light on his case. He was an only child and lived with his single working mother. She ranked importance of PA high (3 out of 4) and participated twice weekly herself. They also had a family car and therefore had independent transport.

6.28.4.7 Case 7 a participating child from Red (≤5th percentile MABC2) group (pure DCD)

This boy was 10 years old, had a verbal IQ of 85 and two parents in full time work. He was the youngest child and had brothers who were 18 years or older. His motor performance ability was low (manual dexterity was at the 2nd percentile, balance at the 16th percentile and aiming and catching at 25th

percentile). However, he rated his enjoyment of PA and predilection to take part in PA as 100%, and his adequacy at 86%. Neither his motor performance ability nor his self-perception changed over time and he clearly loved PA. He was the tallest boy in the school. His parents rated PA as important and participated themselves weekly. They had two cars and, importantly, his older brothers had a keen interest in playing rugby and encouraged him to play. He was a member of a local rugby team, practiced and played in matches twice weekly and thoroughly enjoyed it.

6.28.4.8 Case 8 a participating child from Amber (6-16th percentile MABC2) group

This boy was 10 years old, had a verbal IQ of 79. His motor performance ability was low, but manual dexterity was lowest at 5th percentile, aiming and catching was at 25th percentile and his balance was at 37th percentile. He rated enjoyment of and predilection to take part in PA as 100% and his adequacy at 92%. He loved PA and was part of a community football team that played twice a week. His motor performance fluctuated over time from the Amber to Green group and back to the Amber, but his self-perception did not change over time. His family ranked the importance of PA high (4 out of 4) and participated twice weekly. His parents were divorced but shared his care. There were no other children under 18 years in the family and they had a car. Again the high rating of importance of PA and supportive parents with sufficient resources appeared important factors.

Summary

The factors associated with participation in extra curricular PA were families who ranked PA important, parents who participated themselves frequently and either had a car or few other children under 18. The important child characteristics were an enjoyment of PA and a good self-perception of predilection and adequacy in PA irrespective of their motor performance ability. Furthermore, their self-perception did not change dramatically over time. Some

children with marked motor difficulties rated their enjoyment and predilection to take part in PA high. For them family attitude towards PA, car ownership, and fewer children under the age of 18 appeared to be particularly important prerequisites for these children to participate in extra curricular PA.

Factors associated with lower participation were higher rate of parent unemployment, more single parent families, fewer cars, higher rate of families with two or more children under 18 years, parents rating attitude to importance of PA low and parents rarely undertaking PA themselves.

6.29 Themes from child's perspective interviews

Interview procedure was outlined in chapter five. A child from each group of motor ability, if possible one with a stable and one with a changing profile and one with AC and one without was selected. In addition, one participating in extra curricular physical activity and one not participated from each category was included. Ten children were interviewed and common themes emerged from children who participated and those who did not.

Themes that emerged from interviews with children who participated in extra curricular PA and those who did not are detailed in table 6.29 and table 6.30 respectively. Some of the main themes are described below.

6.29.1 An encouraging adult:

Regardless of their motor ability, children who participated in extra curricular PA mentioned a supportive adult, somebody that took an interest, introduced them to a sport or played active games with them.

"When I was young my Dad erm said to me 'do you want to have a kick about?' and I had a kick about with him and I just got into it, erm I play. Me Dad got me, me Mum and Dad got me into a team and I now play for another team and I'm brilliant."

Table 6.29 Mixed methods analysis grid for children who participated in PA (After Creswell & Plano Clark, 2011)

Face to face interview Themes **For children who participated in extra curricular PA**	**Survey questionnaires data**
1. **Parental support:** children talked of parents taking an interest, organizing enrolment in clubs, watching them or joining in, lifts to and from venues	Ranking of importance of PA to parents (≥3) Parents ranked importance 1-4 (1 being not important)
2. **Siblings to play with:** children talked of siblings, neighbours or cousins to play with	Other children under 18 in family
3. **Enjoyment of PA:** children identified P.E. as fun, they talked of activities they liked outside	Frequency of Parental participation in PA (weekly/ twice weekly)
4. **Participation in community team sport:** football or rugby teams, sense of belonging, regular practice sessions, coaching with an interested adult	Car transport, owned a bike
5. **Facilities nearby:** children 9 and over talked of getting to a play area independently by bike, bus or walking e.g local swimming pool, playing field or somebody's garden or street, having a pet to play with	Parent employment: one or both parent working

Table 6.30 Mixed methods analysis grid for children who did not participate in PA (after Creswell & Plano Clark, 2011)

Face to face interview Themes **For children who did not participate in extra curricular PA**	**Survey questionnaires data**
1. **Parental support:** children did not mention parents taking an interest in PA, or joining in or playing with them	Ranking of importance of PA to parents (≤2) Parents ranked importance 1-4 (1 being not important)
2. **Solitary activity (video games):** children talked of mine craft or other games, rarely of any friends	Other children under 18 in family, Associated characteristics
3. **Dislike of PA:** some children identified P.E. as unpleasant. they talked of fear of the ball, dislike of team games in the playground, others found it boring or preferred other actvities	Frequency of Parental participation in PA (rarely – twice monthly)
4. **Other interests:** music, drama, or other interests the were motivated to do and feel a sense of mastery	Low competency in PA (MABC2 results)
5. **Difficulty finding playmates:** living to far away from other children the same age, difficulty with social interaction	No transport, no bike, free school meals, associated characteristics

6.29.2 Enjoyment of active outdoor games or P.E.

Another theme that emerged was the joy and fun element in movement and that play was incorporated in P.E. lessons. Many of the children cited P.E. as one of their favourite lessons irrespective of their motor ability.

“P.E. it’s like different than most lessons, you get to move around and (pause) do fun things.”

“Lots of good games and in P.E we go to play stuck in the mud, erm, dancing, erm then like we might erm, Simon Says and more good games.”

“I like P.E. because I like to run around and run around”

6.29.3 Somewhere to play

Children talked of the importance of somewhere to play nearby, preferably that they could reach without parents necessarily taking them.

“Ive got a back field so I’ve got massive, like massive grounds, massive back field with loads of football pitches and everything, so I can just go and play there myself”

6.28.4 Somebody to play with

The children who participated in PA talked of having fun with siblings, cousins or children as close neighbours.

“We go up to the park or we go into the house and play on games”

“I play my guitar, I like doing football, I like playing with my brother, I like writing, running and reading”

However, some of those that did not participate mentioned lack of someone to play with, either because their parents worked and childcare arrangements caused the difficulty or they did not live near children of a similar age.

"I go to me Nans almost every day so I don't get to have any friends where I live"

6.29.5 Other interests

Another factor in the children that did not participate in PA was interest in other hobbies or activities and video games, X-Box and PlayStation all featured here. However, some children mentioned playing with pets, or a love of music, dance and drama that they would prefer to do. This was particularly the case for three of the five girls in the study.

"I don't mind P.E., its not like the best, but it's like one of those subjects which sometimes it's good, sometimes it's not good" … I'd change the school curriculum and erm have instead of music and drama once a week I'd have it twice a week definitely"

Summary

Analysis of both the group and individual data indicated that children with typical motor ability and a stable self-perception were more likely to participate in PA. However, closer analysis of the individual data revealed that some children from all categories of motor ability were able to participate and enjoy PA, providing they had appropriate environmental support and opportunities. This support was even more important for the children with low motor ability and associated characteristics, as they are at greatest risk of the most disadvantages if they are not given opportunities for active participation in PA. This information offers areas for future intervention to support families to facilitate participation in PA for all children, especially those with DCD.

6.30 Overall summary

Children with and without DCD aged 7-14 years were identified and assessed at baseline (T1) for a profile of their characteristics. When categorized by motor performance ability three distinct groups emerged, the children in the lowest fifth percentile of motor ability group had the greatest difficulty in everyday tasks, lower IQ, high prevalence of two or more associated characteristics and SEN. They also had a higher rate of first-degree relatives with developmental disorders. They also had a distinctive stable pattern of motor progression, with limited variability, over a two-year period. Their self-perception, however, did not differ from the other two groups, but they had a very low rate of participation in PA. The children with moderate motor impairment were indistinguishable from TDC in motor performance over time (by T3), but they had a highly variable pattern of motor progression. Interestingly, they also had a very low rate of participation in PA. The TDC had a less variable pattern of motor progression. Prevalence of participation in extra curricular PA was highest for those with typical motor ability, but case analysis identified that a child from all motor categories either with or without AC was able to participate, provided they had sufficient contextual support.

CHAPTER 7 SUMMARY, DISCUSSION AND CONCLUSION

7.1 Study aims

The aim of this study was to establish whether children with DCD with different severities of motor impairment had different profiles of characteristics. Another aim was to establish whether they had different motor progression over time. In addition, children's experiences of participation in physical activity were sought by choosing children with different characteristics and stable and changing motor profiles to better understand factors associated with their participation in extra curricular physical activity. Using a mixed quantitative and qualitative study design within the framework of Bronfenbrenner's bio ecological model permitted greater understanding of children's inter-individual differences and contextual influences. A number of questions were addressed regarding the profiles of children with DCD:

1. What are the characteristics of children with different severities of DCD compared to children without DCD?

   These included their:

   - Motor characteristics
   - Associated characteristics
   - IQ
   - Ability to take part in everyday activities
   - Socio-economic and family context
   - Self-perception of their adequacy, enjoyment and predilection to participate in physical activity

2.1 How stable are the motor characteristics or do they change over time?

2.2 How consistent are their self-perceptions of their adequacy, enjoyment and predilection to participate in physical activity or do they change over time?

3. How do the characteristics and stability or change in motor ability and self-perceptions impact experiences of participation in physical activity from the child's perspective?

Part one of the study examined the motor and other profiles of schoolchildren aged 7-14 years with and without motor difficulties. Part two followed their motor progression and child perceptions of their motor ability over time. Part three examined a smaller subset of children, identified with different characteristics and progression over time, to seek their experiences. The findings are used to inform better understanding of how different severities of motor impairment and the context of DCD can impact on children's experiences of participation in physical activity.

7.2 Summary of study findings

A mainstream school based cohort of children with and without movement difficulties, identified by their teachers and identified with DCD according to DSM5 criteria were compared. Analysis comparing the children with and without movement difficulties did not identify differences in either socioeconomic status (SES) or age. However, when groups were categorized by their different motor performance ability, analysis of variance identified significant differences between the groups. The group in the lowest 5th percentile of motor ability had a very distinct profile of characteristics. Yet, there was no difference between the groups in the mean self-perception of their motor ability.

The second part of the study identified that the groups classified by motor ability progressed differently over time. Repeated measures analysis of variance identified that the children with different severities of motor impairment had

distinct and different trajectories from each other. Those with the most severe motor difficulties were most likely to show persistent motor difficulties. The children with moderate motor impairment all showed improved motor performance over time and were no longer significantly different to typically developing children by the end of the study. Repeated measures analysis of variance of the children's self perception of motor ability over time, however, did not show any difference between the groups.

In the third part of the study children, who were typical and atypical cases from each of the motor ability groups, expressed different experiences of participation in physical activity. Participation and enjoyment of physical activity was not necessarily related to the children's motor ability or the progression of their motor ability over time, other factors were identified. The implications of these findings will be discussed in the following sections.

For data analysis a sample size analysis was performed using a significance level of 5%, a power of 80% and, based on a large effect size (d=.8); a sample size of 28 was required (Dunlop & Myers, 1997). The sample size for this study was 34 at baseline and therefore met these requirements. However, to enable statistical comparison of the three groups and in order to keep the power of 80%, the effect size was very large (d=1.5) and the sample size required was 8 in each group (Hinckle et al., 1994). The sample size of this study met these criteria for two out of the three groups (severe n=10, moderate n=7 & typical n=17). Repeated measures analysis of variance was used to investigate whether the groups differed in mean test scores and Bonferroni post hoc tests were performed to compare the mean scores of each group with each other. Alpha was set at 0.05.

Baseline data compared potential confounding variables of age and SES and revealed no significant differences between the groups, so that they could be considered to have an equal effect over time. However, IQ was also compared between the groups and showed that the children in the severe group (lowest

5th percentile of motor ability) had significantly lower composite and verbal IQ scores than TDC. Since this could potentially influence the children's progression, IQ scores were used as covariant in the final analysis but this did not change the outcome of results in that the groups still differed in their motor performance ability and progression over time.

7.3 Profile of characteristics in DCD

7.3.1 What are the characteristics of children with different motor severities of DCD?

Children with DCD are often referred to as heterogeneous and, although a number of studies have searched for subtypes, there has been little consensus. One criticism is that most have investigated from information processing (IP) theoretical perspective and therefore narrowed the focus of investigation. Interest in motor development theory is moving away from a pure IP approach and starting to take account of the environmental context of development. This approach is encompassed by the dynamical systems theory, and some researchers are starting to propose combining both theories to take a hybrid approach to investigate the difficulties associated with DCD (Wilson et al., 2017b). Another source of heterogeneity in DCD is the presence of co-occurring conditions (often referred to as comorbidity). Although this has also been investigated it has not typically been studied in conjunction with the severity of the motor impairment. Indeed, the majority of DCD studies report results for children <15th percentile of motor ability and do not distinguish between different severity of motor impairment. Therefore, the main focus of this study was to examine the characteristics of children with and without DCD for different motor abilities.

The children in the lowest 5th percentile of motor ability appeared to be a very distinct group across a number of different domains.

7.3.1.1 Motor characteristics

The motor difficulties in the severe group of this study were significantly different to the moderate and TDC groups in manual dexterity, aiming and catching and balance on MABC2 (P< .001), indicating that the severity and nature of motor difficulty is distinct. It is well established that the impact that this motor profile has on function in daily life is profound and interferes with activities of daily living, family life, schoolwork and play. Moreover, the evidence of wider deviance from typical development in cognitive and behavioural domains in this study and others (e.g. Schoemaker et al., 2013; Gillberg, 2010) indicates that the motor difficulties in the ≤5th motor percentile group of children may arise from different routes than those of children with more moderate motor impairment. For example, Peters, Maathuis & Hadders-Algra (2011) found that in a sample of (n=253) school age children (mean age 8 years) those with <5th percentile on MABC had a higher prevalence of more complex minor neurological dysfunction than those at the 5-15th percentile and TDC (54% vs 17% vs 10%). This further supports the notion of a more atypical pattern of development in children with motor impairment in the lowest 5th percentile.

The children with moderate motor impairment (6-16th percentile) in this study did not differ significantly from the children in the typical motor ability group (>25th percentile) on balance or aiming and catching and only differed in their manual dexterity (p<. 001). However they were significantly different to the children in the lowest motor ability group across all motor domains (p<.001), adding further support that children with DCD in the lowest motor ability group have distinct profiles that differ from TDC and from children with moderate motor ability.

The children with the highest motor ability (>25th percentile) displayed typical performance across all motor domains.

7.3.1.2 Associated characteristics

The tools in this study for screening profiles were carefully chosen psychometrically robust tools and a conservative 5 % cut-off used in order to minimize false positive results. Even so, the children in the lowest motor ability group had a much higher prevalence of associated characteristics (AC), of other developmental disorders such as ASD and ADHD, than either of the other groups. They were also more likely to have two or more ACs compared to the children in the other groups. In this study 90% had two or more ACs and this entire group were male. Other studies have found children with DCD with co-occurring conditions. For example, Lingam et al. (2010) found 7-year-old children in a large UK population cohort at risk of DCD, below 15th percentile of motor ability, likely to have additional traits of other developmental conditions. Gillberg (2010) also noted a higher prevalence of co-occurring disorders in a Swedish population sample of children with neurodevelopmental/ neuropsychiatric disorders and suggested that they are difficult to separate and share genes, environmental risk factors and symptoms. Therefore, the finding that 90% of children in the lowest 5th percentile of motor ability in this study had 2 or more ACs finds support in other studies.

The response rate for the parent questionnaire was lower for the group with moderate motor ability (6-16th percentile) and there were fewer children in this group, so the results should be interpreted with caution. However, two of the children in the moderate motor ability group also had associated characteristics but, in contrast to the lowest ability group, none had two or more ACs. Another interesting finding was that the typical motor ability group (>25th percentile) also contained 5 children with AC, one with 2 or more AC. From this we can conclude that children with ACs are distributed throughout the population of motor ability, but those with 2 or more ACs are much more likely to be concentrated in the children with DCD in the lowest 5th percentile of motor ability.

Recent analysis of children at risk of DCD aged between 7-9 years found a higher prevalence of co-occurring conditions in those <5th percentile of motor ability (Schoemaker, Lingam et al., 2013) and supports this view. Schoemaker and colleagues used logistical regression in a large UK population based cohort (n=6959) to determine if the severity of motor difficulties related to co-morbidity in children at risk of DCD and found that the 7-9 year old children with severe motor difficulties (n=289) had a prevalence of 20-25% higher risk of problems in other developmental domains, even accounting for IQ and parent related confounding variables. Furthermore, they found that children with moderate motor difficulties (n=951) had a prevalence of 5% higher risk than TDC (n=5719). This further supports the findings that children with severe motor impairment are distinct from those with moderate impairment and from TDC and represents a much higher risk of developmental disadvantage.

7.3.1.3 IQ

In addition there were significant group differences on mean IQ scores on KBIT2 ($p < .001$). The lowest motor ability group had the lowest mean composite and verbal IQ scores of all the groups, although post hoc tests revealed that only the difference between them and the children with typical motor performance (>25th percentile on MABC2) was significant for composite IQ and verbal IQ ($p<.001$). Other studies have also reported that children with DCD have lower IQ in comparison to those without DCD. For example, Flapper and Schoemaker (2013) found significantly lower IQ in 5-8 year old children with DCD < 15th percentile on MABC (according to DSM IV criteria) co-morbid with SLI than those with SLI alone. Furthermore, 66% of their sample of children co-morbid for SLI and DCD were in the lowest 5th percentile of MABC, adding further support to the present study findings that this group of children has very distinct characteristics.

This is important and may indicate that children in lowest 5th percentile of motor ability represent a separate subgroup of children with broader difficulties across

a number of domains including the motor domain, but this would need to be verified with more studies. There are also implications, which may indicate developmental differences relating to the CNS, as in this study the ≤5th percentile group had a 40% incidence of first-degree relatives with a developmental disorder in their family history, compared to 29.4% incidence for children who scored in range of TDC at baseline. However, and importantly over time, two children (11.76% of the group) of the TDC group with first-degree relatives with a developmental disorder subsequently changed group into the impaired range. Therefore, 7-14 year old children in lowest 5th percentile in this study were more likely to have a first-degree relative with a developmental condition than children whose motor ability remained in the typical range over time. This suggests a strong heritability associated with DCD with the lowest 5th percentile of motor ability. This was an interesting finding since the sample had been deliberately derived from a population based school sample, in order to avoid referral bias associated with the greater concentration of children with co-occurring conditions of clinic samples.

However, one consideration is that a high proportion of children in this study sample had symptoms of ASD and ADHD, both of which are thought to have high heritability and involve differences in neural substrates, which may account for some of the differences. Conversely, the one child without AC in the lowest motor ability group also displayed the same difficulties across domains (e.g. poor handwriting and spelling, lower verbal IQ, poor motor control in all subgroups and low score on DCDQ), which implies that the difficulties are associated with DCD and not ASD or ADHD per se. However, only similar studies with careful screening for ACs and larger sample size will determine whether this is the case.

The group of children with moderate motor difficulty (6-16th percentile MABC2) had lower mean IQ scores than the group with typical motor ability, post hoc analysis revealed that the difference between them just reached statistical significance (p=.053) for composite IQ score, and significant difference in their

mean verbal IQ scores ($p<.001$). These results may be erroneous due to the small sample size of this group. However, the trend showed that they had lower mean IQ scores than the group with typical motor ability and higher IQ scores than the group with lowest motor ability. Although the mean IQ score difference between them and the lowest motor ability group was not significant, it still points to the children with DCD in the lowest 5th percentile of motor ability having distinct characteristics. Unfortunately, it was difficult to ascertain the true frequency of first-degree relatives with a developmental disorder in the family for 6-16th percentile group, as few questionnaires were returned. However, of those returned, only 28.6% reported a relative with a disorder, which is still much less than that of the 5th percentile group. Taken together the higher prevalence of first-degree relatives with a developmental condition, the higher prevalence of two of more ACs and the lower mean IQ in the group with the lowest 5th percentile of motor ability indicates a group of children, not only distinct from TDC, but also distinct from those with moderate motor impairment.

7.3.1.4 Ability to take part in everyday activities

The parents reported that the ability of the children with the lowest motor ability to take part in everyday activities was problematic. This group had significantly different scores to the other two groups when examined on DCDQ '07 ($p= .001$). However this may have resulted from difficulties arising from the symptoms of the AC as 90% of the children had co-occurring AC, only larger studies carefully detailing AC will be able to verify this. Although it is becoming apparent that DCD with AC occurs more frequently than not and is likely to be encountered in practice. Nevertheless, it does identify that children in the severe group encounter more difficulties in daily function that impacts on all areas of occupation at home than the other two groups and confirms the serious nature of the condition. School life was also affected as the children in this group had a much higher incidence of SEN and handwriting difficulties. Both of these potentially have a large impact on progress at school and seriously disadvantage children unless adequate provision is available for them. This group proved easier to identify, as teachers correctly identified 90% of the

children in the severe motor impaired group and 100% of the parents correctly identified that the children had problems, indicating that teachers and parents of the children in this study found it much easier to identify the children's difficulties in the severe motor impaired group.

The parents and teachers did not identify the difficulties as readily for the group with moderate motor difficulties, possibly as they were subtler in nature. However, studies indicate that these groups have difficulties resulting in reduced function and adverse consequences from their impaired motor ability (Wang, Tseng, Wilson & Hu, 2009). The mean DCDQ '07 score differed significantly from the severe group but not the TDC group. One possible explanation was that the TDC group also contained some children with AC and their parents highlighted difficulties associated with these. Interestingly, the moderate group was distinct from the severe group with significant differences in all motor domains, yet only differed significantly from the TDC in manual dexterity. Perhaps this was not sufficient to alert the attention of parents to functional problems.

7.3.1.5 Self perception of adequacy, enjoyment and predilection to take part in PA

The children's self rating of the adequacy of their motor ability, predilection to take part in physical activity (PA) and enjoyment of it (rated on CSAPPA) did not differ significantly between the groups at baseline. This is an interesting finding, since the extant literature reports that children with DCD have low self-efficacy in physical ability (Losse et al., 1991; Cantell, Smyth & Ahonen, 1994; Skinner & Piek, 2001; Poulsen et al., 2008; Cocks et al., 2009) and some report that children with DCD have significantly lower self-efficacy in physical ability than TDC (Cairney et al., 2005; Silman et al., 2011). This is thought to impact participation in physical activity. According to Harter's competence motivation theory (Harter, 1982) the assumption is that children with high-perceived competence in a specific domain are more motivated to participate in that domain, whilst those with low perceived competence are less motivated to

participate. One would therefore expect children with DCD to have low perceived competence in physical abilities, especially the children in the lowest 5th percentile of motor ability. However, this was not the finding in this study, despite the fact that the children with DCD participated less in PA.

Other studies have also found that children with motor difficulties do not necessarily have low perceived athletic competence and, further, have found no difference in perceived athletic competence between children with motor difficulties and TDC (Pless et al., 2002; Fliers et al., 2010; Noordstar et al., 2014; Toussaint et al., 2016).

It is possible that age related differences have influenced the results across studies. Harter (1988) differentiated between stages of self-awareness at different ages of children by describing the emergence of self-description at three developmental periods. The early period occurs at approximately at age 5, where the child observes and judges others, but does not realize that others can do the same to them and so is not able to critically evaluate the self directly. The second stage, around 6-7 years is where the child comes to appreciate that others are observing and evaluating the self and worry about criticism and being laughed at, but are still unable to critically observe the self directly. The third stage, usually around 8 years, where the child becomes interested in evaluating their own performance based on the standards that other people have for the self. They can begin to incorporate the observations of others into their own self-perceptions. They start to internalize these expectations into self-standards and develop the capacity for self-criticism. This marks the emergence of the ability to compare oneself to others (Harter, 1988, p 61). However, as all the children in the present study were aged 8 or older, except one child, age and developmental stages of self-perception are unlikely factors in the results of this study.

Another area for consideration is the influence of children's self-esteem. Harter (1988) suggested that one's self–esteem is based on evaluations of judgments

of adequacy of the self across different domains in one's life. She suggested a domain specific approach to profile these differences in sense of adequacy across the domains. For example, a child may feel very competent at schoolwork, less adequate in peer relations and relatively incompetent in the domain of athletics. In addition, Harter (1988) suggested that whilst competence is considered one's source of self-worth, acceptance and positive regard are also important. Children with high self-worth feel that significant others (parents and peers) accept them, support them and hold them in high regard. Furthermore, perceived positive regard from significant others appear strongly related to self-worth, suggesting that children (aged 10-13) adopt the attitudes and opinions that they feel others hold toward the self. In addition, the degree that one feels competent in areas where success is important has the ability to discount the importance of domains where one feels less adequate is also an important determinant of self-worth (Harter, 1988, p72). This could point to the importance of the attitude of significant others (parents and friends) towards the child that can contribute to positive self-esteem and over ride the impact of motor difficulties on self-perception. Children of all levels of motor ability in this study described fun P.E. lessons, enjoying playing out with siblings, being a member of a team and reported parental encouragement and physical and moral support to take part in PA. It therefore suggests that the positive regard and attitude of significant others can have a powerful positive influence on self-perception and motivation towards PA.

Although the results in the extant literature appear equivocal, comparison of studies examining perceived self–efficacy in DCD is difficult due to methodological differences. Some of these include varying levels of adherence to DSM diagnostic criteria, different stages development of self-perception covered by large age range (6-17 years) of the children studied, few descriptions of any account of co-occurring conditions, different questionnaires used (e.g. Harter, CSAPPA, Dutch self perception profile for children) with questions that impact slightly different domains with different importance attached to the task described. Whether the questions include enjoyment or whether adequacy alone is questioned could also potentially impact results. The

context of the physical activity could also have a bearing, for example, competency at a lab based shuttle run could be perceived differently by children compared to the physical activity of their choice.

However, as this study indicated, children with all motor abilities can enjoy and express motivation to engage in physical activity. Children aged 8 and over are capable of making global judgments of their overall worth as a person and evidence supports two primary determinants of a child's self-worth (Harter, 1988). The first involves internalization of attitudes that significant others hold towards the self, the more one feels support and acceptance from others the higher one's self-worth. The second involves the degree to which one feels competent or adequate in areas where success is important, and can discount the importance of domains in which one is not competent results in high self – worth (Harter, 1988). One's sense of self has a major impact on one's emotional life, which in turn influences children's motivation and behaviour (Harter, 1988, p 77). The results from this study indicated that factors other than motor ability were important in the children's perception of their adequacy, predilection and enjoyment of physical activity for the children in this study (mean age of 10 years, SD 1.66). The inclusive nature of the school and of P.E. lessons may have been important factors. Children's age may also be an important factor and this could potentially have implications for intervention, as it is easier to engage primary school children in physical intervention programmes before they become disillusioned and lose confidence and motivation to engage with physical activity.

Summary

It is evident from the data at baseline that the group of children with severe DCD, i.e. those in the lowest 5th percentile of motor ability, appeared to have very distinct characteristics from the other two groups in terms of their lower verbal and composite IQ scores, the increased co-occurrence of two or more AC and higher rate of SEN. Their motor difficulties tended to be across all subtests of MABC2, differed significantly from TDC in all subtests ($p < .001$) and

their difficulties were more likely to be identified by their teachers or parents. However, not necessarily identified by the children themselves, as there was no significant difference between the self-perceptions of the groups with different motor ability.

7.4 How stable are the motor characteristics or do they change over time?

The children from each group of motor severity were followed over time and any motor change was recorded using repeated measures of the MABC2. The same experienced OT administering the MABC2 in the same settings each time, which increased consistency and reliability of the repeated measures. Furthermore, motor change was not only quantified, but an effort was also made to capture clinically meaningful change in motor ability. Change was therefore determined using three methods: total MABC2 score, the MABC2 traffic light classification system and Holm et al. (2013) smallest detectable change (SDC) (+ or -10 points total MABC2 score).

7.4.1 The children in the group with lowest 5th percentile of motor ability

The children with the most severe motor impairment at baseline appeared to have a distinct pattern of motor change over time. The most striking feature was that none of the children in this group changed group membership over time, all remained in the most severe motor impaired group.

The next important finding was that repeated measures ANOVA of their motor ability showed that this group differed from the other two groups over time ($p<.001$). Even after accounting for the group mean lower IQ using ANCOVA this group was still statistically different from the other two groups ($p<.001$). Importantly, this indicates that they followed a different motor trajectory and further confirmed the differences found at the baseline of the study.

The persistent nature of the their motor difficulties was further supported by the fact that there the majority (77.8%) had no change in the individual scores for SDC (+ or - 10 points MABC2 total score) for each member of this group. This indicated that they had no clinical difference in motor ability from their baseline score over two years. Furthermore, although 22.2% of this group improved >10 points on MABC2 it was of insufficient magnitude to change group. However, no children from this group deteriorated over time. Therefore, the children with the lowest 5th percentile of motor ability had a general picture of stability of their motor ability over time as none improved sufficiently to leave the lowest 5th percentile of motor ability. This sets them apart as a distinctive group both at baseline and over time with persistent motor difficulties and answers two of the research objectives; 1) this group had distinctive profiles of characteristics and 2) their motor characteristics remained stable over time.

This may have important implications, both for identification of children in the lowest 5th percentile of motor ability and for intervention. First, they are much more likely to have co-occurring characteristics and a broader range of additional problems, which can seriously impact their function in daily life and these will require careful assessment. Kirby (2005) has long acknowledged the existence of conditions overlapping with DCD and called for screening across all developmental areas, preferably in schools. The evidence from this study suggests that this should particularly be targeted at the children with lowest 5th percentile of motor ability. Second, this evidence strongly suggests that the children in this group do not spontaneously clinically improve over time and so intervention is vital. Furthermore, because of their very different profiles and very different motor trajectories, they may require specific intervention, which is different to that required by children with moderate motor difficulties.

7.4.2 The children in the group 6-16th percentile of motor ability

The children with moderate motor ability (6-16th percentile on MABC2) behaved very differently over time. Two secondary age children from this group were

lost to follow up and unfortunately the attrition rate in this group left insufficient numbers to give an adequate sample size for statistical analysis. Nevertheless, the analysis was undertaken to examine general trends and was augmented with case study contextual data and interview. Therefore, whilst interpreting these results with caution, they do give an insight into motor change over time.

All the remaining children in the moderate motor ability group improved over time and scored in the typically developing motor ability range by data point three, giving the impression of resolution of their motor difficulties. There was no statistical difference between them and the typically motor ability group over time, making them indistinguishable. Yet, the trajectories within this group were highly variable, nonetheless all improved their total MABC2 score by greater than 10 points over time and, by Holm's definition, showed a clinical difference in their motor performance. However, the pattern was not necessarily one of steady improvement for all, some children improved, then deteriorated then improved again. For example, the two girls started low and increased to the next percentile each data point into the typical range, whereas one boy with ASD started at the 9th percentile, dipped to the 5th percentile before ending on the 37th percentile. Another boy, with characteristics of ODD, showed less dramatic variation but still fluctuated over time, starting at the 9th percentile, moving to the 37th percentile, then the 25th before ending at 50th percentile for the final data point. This illustrates the extent of variability that the moderate group displayed in direct contrast to the stability displayed by the group in the lowest 5th percentile of motor ability.

It is difficult to draw useful conclusions about the reasons behind the stark difference in the relative trajectories of the two groups, apart from surmising that they represent different subgroups of children with motor difficulty. However, with such small group samples it would be unwise to accept this hypothesis without further testing with adequate sample sizes. Nevertheless, the girls in the group may provide a small insight into possible sex differences. Both girls improved incrementally over time to reach scores in the typical range, yet both

rated their enjoyment and motor performance in the (impaired) suspect DCD range of the CSAPPA, despite improving their performance over time. This could be a case of low expectations and low self-confidence. Both girls continued to have low scores in aiming and catching over time and balance scores above the 50th percentile, but confessed they had little predilection to participate in physical activity.

In direct contrast, two boys in this group, with highly variable performance, expressed great enjoyment and predilection to take part in PA despite scoring similar motor scores to the girls. One had associated characteristics and the other did not. This may be less to do with presence or absence of AC and more to do with the effects of cultural influence on role expectations for boys and girls and warrants further study.

The conclusion we can draw from these data is that the children with moderate motor ability (6-16th percentile) in this study all improved their performance over time to reach typical motor ability by the 3rd data point. They may represent the lower end of a normal motor continuum and their motor ability appears variable. However, those that were tested for a 4th data point had deteriorated and we could conclude that it may be unstable because they were unable to sustain the higher level of motor performance.

7.4.3 The children in the group with 25th percentile and above of motor ability

The children who scored in the typical motor development (>25th percentile on MABC2) at baseline displayed yet another pattern of motor change over time. Over half (53%) showed no change in motor performance, they remained within <10 points MABC2 total score over time, demonstrating stability in their motor ability. One quarter of the children improved their motor performance and one quarter deteriorated over time. However, 2 of the 4 children that deteriorated over time had known diagnoses of ASD and ODD and both changed category

into the 6-16th percentile, moderate impairment range of motor ability. The other two had no known diagnoses, one remained in the typical range and the other (who had been adopted and had unknown family developmental history) changed to the 6-16th percentile. Although some children improved and some deteriorated, the majority 82% of this group remained in the typical range (≥25th percentile of motor ability) over time and had stable motor ability. We can assume that some motor variability is to be expected in typical development, but that it does not generally impact on function. However, children at the lower end of typical motor ability appear more likely to encounter other difficulties, for example have AC, which may have a detrimental effect on their motor and other function.

Summary

Distinct patterns of change emerged between the groups of children when they were categorized by their motor ability at the study baseline. Despite some children changing groups over time, none of the children from the lowest 5th percentile changed group, but persistently remained impaired at the lowest level of motor ability over time. Their motor performance was stable but poor, with no clinical improvement, in contrast to the 6-16th percentile group, which was highly variable, and 100% improved motor performance to ≥25th percentile over time. Conversely, the children who started ≥25th percentile of motor ability showed a mixture of patterns of change, but 82% remained in the typical range over time demonstrating relative stability of motor performance over time. These findings are of interest because this was not an intervention study and so any improvement in motor performance was spontaneous and reflected progression in motor development.

7.5 How stable are the self-perceptions over time?

Group statistical analysis of self-perceptions revealed little information to predict which children would improve their motor ability over time, as there was no significant difference between the groups for self-perception of enjoyment, adequacy or predilection to take part in PA at the start of the study or over time

despite their differences in motor ability. Harter (1988) suggested that one's domain specific judgments and one's self-worth are moderately stable for most children over relatively short periods of time (e.g. a school year) and these results appear to support that.

However, examining the individual profiles of the children from each group revealed a different story. The three boys who initially scored in the typically developing range of motor ability, but then deteriorated over time, all ranked themselves in the at risk range of the CSAPPA by data point 3. They appeared to be aware of their poor motor performance. Two of the boys had ACs, one had ASD and the other ODD and difficulties in other areas. The other boy was adopted and had an unknown early history.

Conversely, two girls and a boy, who initially scored in the 6-16th percentile of MABC2 but improved over time to the typical motor ability range, ranked themselves in the at risk range of the CSAPPA by data point 3. Their self-perception had deteriorated over time, despite their improving motor performance. This suggests a lack of confidence in motor skills coupled with a lack of enjoyment or interest in PA had influenced their perception.

The children in the lowest motor ability group did not exhibit self-perceptions that matched their motor ability, all remained in the lowest motor category over time, yet individuals had a range of self-perceptions. For example, two boys improved their motor performance by more than 10 points over time, yet one rated his self-perception in the at risk range of the CSAPPA and the other did not, while some of the others rated themselves high on the CSAPPA. Clearly enjoyment and participation in PA was related to factors other than motor ability for them. Interestingly, Pless et al. (2002) also found a mismatch between self-perception and motor performance in their study of children with DCD. They found that high perception of self-competence did not necessarily relate to participation in PA, and some children with low self-perception did participate. Noordstar et al. (2014) used a Dutch self perception profile and did not find a difference in perceived athletic competence (PAC) between children aged 7-12

years with DCD (DSM IV criteria, IQ >70, <15th percentile on MABC) and matched TDC. In fact most children had a high PAC 64.5 % of the DCD group and 86.8% of the TDC group. However, there were large individual differences within the DCD group. They also found no difference in organized PA between the groups, but there was a significant difference between the groups for unorganized PA. They surmised from this that relationship between perceived athletic competence, motor ability and participation in PA is complex and is a supposition supported by this study.

Examining contextual information through an ecological lens permitted analysis of other potential influences on PA, such as parental attitude, available resources and suitability of the physical environment and the child's beliefs and motivations permitted analysis at the inter-individual level. In this study parent questionnaires, together with child interviews, facilitated collection of these data.

7.5.1 Ecological analysis with Bronfenbrenner's model:

At the macro system level of analysis:

On the surface the study neighbourhood appeared typical for the UK, as it had an average level of unemployment and an average utilisation of outdoor space for exercise when compared to England as a whole. However, the number of children in low income families was higher than average and the income deprivation indices, based on 2015 figures, was higher than average. Additionally, the borough had a higher than average number of children eligible for free school meals in 2014. So, although parents were in employment, their pay did not sufficiently cover their basic costs.

At the mesosystem level of analysis:

The school had robust SEN policy and a higher than average number of pupils with special educational needs, and also a very high level of pupils eligible for

free school meals. It was well resourced and had committed and caring staff. The children attending the autism resource bases spent most of their time in classes with their year group in the main school and so had similar experiences in class.

At group level analysis the Red group had the lowest participation in extra curricular PA, less than half the level of TDC (20% compared to 52.9%). In addition, the Red group parents participated less in PA than parents of TDC (50% compared to 64%) but more than the Amber group. However, there were a greater proportion of families with siblings with developmental disorders in the Red group (40% compared to 29.4% in TDC), which could account for the parents' difficulty participating in PA.

Interestingly, the parents of children in the Red group ranked the importance of PA higher than those in Amber group and a little lower than TDC (50% compared to 58,8%). Although the parents in the Red group had a lower incidence of unemployment than those of TDC (10% compared to 35.3% in the Green group) and a similar rate of car ownership, their children participated much less in extra curricular PA. Thus, despite parents considering participation in PA important, the pressure of managing family life with 2 children with developmental disorders appeared to inhibit participation.

The microsystem level of analysis:

The children's characteristics results appear to agree with the concept of ESSENCE, proffered by Gillberg (2010), whereby the co-existence of disorders and the sharing of symptoms is the rule rather than the exception in developmental disorders. This was particularly evident in the Red group (those with lowest motor ability) as there was a much higher concentration of children with multiple symptoms, 80% had symptoms of ASD/ADHD/DCD and 10% had symptoms of ASD/DCD, whereas only 10% had symptoms DCD alone. Considering their ecological environment, 60% of this group had free school meals and 40% had a first-degree relative with a developmental disorder. It is evident that this group encountered multiple indices of adversity.

This compared to the Amber group, who had moderate motor impairment, and did not have any children with three symptoms of developmental conditions, 28.6% had ASD/DCD and 14.3% had ODD/DCD and 14.3% had hearing impairment/DCD. Adverse ecological environment was not as evident in this group, only 28.6% has free school means and 28.6% had a first-degree relative with a developmental disorder.

The green group had only one child with symptoms of two developmental disorders (ASD/ADHD) and only one child in each category of other developmental disorders, which showed that these developmental disorders could be present without movement impairment. The ecological context of this group is of some interest as 47.1% had free school meals (much higher than the amber group) and 29.4% had a first-degree relative with a developmental disorder (similar to the amber group), so demonstrating some indicators of ecological adversity, although not as severe as that of the Red group.

The high prevalence of children with ASD in the Red group introduced the possibility that poor comprehension might impact the study results, but the KBIT2 results did not bear this out. The Red group had 9 children with ASD but only 4 had low KBIT2 scores. The Amber group had 3 children with low KBIT2 scores, but none of them had ASD. The Green group had only one child with low KBIT2 score and he did not have ASD.

Summary

Analysis of the ecological context of the children in the three groups revealed that the children in the Red group encountered more barriers to participation in PA than the other two groups.

However, group analysis of the children's self-perceptions appeared stable over time, as there was no difference between the groups in their self-perception according to the CSAPPA scores, although there were large inter-individual differences. These were investigated by cross case analysis.

7.6 The child's perspective of experiences of participation in physical activity

The themes that emerged from interview data and from the cross case analysis of cases of children who participated in PA, were present across all motor abilities and therefore all trajectories of motor progression. Bronfenbrenner's bio ecological framework helped to classify the elements at various levels: at the child level IQ and motor ability did not appear important, it was the enjoyment of active games and interest in playing that was important. At the microsystem level a positive parent attitude to PA was important, so that encouragement from parents or older sibling and car transport by a parent to venues, sufficient financial resources to permit this, someone to play with (whether parent, sibling, pet or friend). At the mesosystem level a space to play or easily accessible local amenities, well run local team sports, choice of activity and fun P.E. lessons at school that consistently emerged as facilitative.

The themes that emerged from the children who did not participate in PA also appeared not to be dependent upon motor ability or IQ at the child level, themes such as fear of being hit by a ball, lack of enjoyment of active games and preference for sedentary games. At the microsystem level themes such as lack of resources or transport, siblings with additional needs, lack of playmates and parental attitude that ranked PA of lower importance. Although the mesosystem environment was the same as that for the children who participated in PA it did not appear sufficient to facilitate participation for these children.

Summary

Children without DCD participated in PA more than children with DCD and the children in the lowest 5th percentile of motor ability participated the least. However, irrespective of level of motor ability, presence or absence of DCD or AC, some children participated in PA, whilst others did not. From the interview data the most salient factor to facilitate participation was the presence of

encouragement from parents with adequate resources, or significant others, and a positive attitude to PA. This is encouraging and can inform intervention for children with movement difficulties.

7.7 Issues of consensus with the identification of motor difficulty

DCD is a complex heterogeneous condition, not always well understood or recognized by professionals. In this study teachers were asked to identify children thought to be typically developing and those with potential motor difficulties. Parents of all the children were then asked to complete questionnaires relating to movement difficulties (DCDQ ’07) and all the children were assessed with MABC2 by an experienced paediatric OT. The study revealed differences between the identification of children’s motor difficulties by parents, teachers and MABC2 with only 53% consensus between them. Interestingly, parents identified five children who scored above the 16th percentile on MABC2, but four of these children, when tested again over time, were subsequently found to have objectively measured movement difficulties. This only serves to illustrate that parents know their own children best and raises questions about awareness of DCD among teachers. Moreover, Barnett (2008) found that different tests identify different children because of their slightly different constructs. This further supports recommendations by Blank et al. (2012) that multiple sources are consulted for DCD diagnosis. However, Blank et al. (2012) do not recommend use of DCDQ for population based screening for DCD because of its low sensitivity and Missiuna et al. (2011) found that, even using the conservative 5% cut off for DCDQ and CSAPPA, they still found 29% false positive identification of DCD in a large population based study. See Schoemaker & Wilson (2015) for a review of the screening tools for DCD. Nevertheless, this study, although it used a school population rather than a clinic population, still targeted children identified by teachers rather than population screening. Furthermore, Rodger, Ziviani, Watter, Ozanne, Woodyatt & Springfield (2003) endorse the need for multiple sources of information to reflect the different perspectives (caregiver report, observation,

standardised test and self report) in order to address function and participation adequately in DCD.

Only seven of children in this study sample (20.6%) identified self-reported motor difficulties at the baseline, whereas 50% were identified by the MABC2. However, subsequent testing and follow up revealed ongoing motor difficulties in the children identified by the MABC2 and an additional three children subsequently rated difficulties over time (although not supported by MABC2 scores). This finding indicates that self-perception of motor ability and predilection and enjoyment of PA are dependent upon factors other than motor ability.

Summary

DCD is not well recognized, among teachers, teachers did not identify one child in the severe motor impaired group with motor difficulties, whereas all the children with AC and motor difficulties were identified. It may point to the greater ease of identifying behavioural characteristics and calls for facilitating greater awareness of motor difficulties among teachers. This was apparently the case for parents too, as parents identified 5 children with DCDQ who scored above 16th percentile but had AC. The consensus for identifying DCD among teacher, parent & MABC2 was only 53%, which potentially leaves nearly half of children with DCD unrecognized.

7.8 Discussion of study variables and limitations of the study

Consideration of the choice of some of the variables and limitations in this study helped interpret some of the findings.

Cohort size

The relatively small cohort of 34 participants dictated group comparison with large effect sizes for statistical analysis and was restricted by the number of children recruited to each group. The group in the 6-16th percentile of motor

ability did not have sufficient numbers for statistical analysis; however, supplementary data from mixed method analysis permitted another form of inter-group comparison. However, the other two groups were large enough to permit statistical analysis between the TDC and children in ≤ 5th percentile motor ability group and also benefitted from addition contextual data.

Random sample

A random sample reduces the possibility of recruiting an unrepresentative sample and permits the generalisation of results. However, this generally requires large numbers of participants and more resources in terms of time and money, which is particularly true for longitudinal studies. Instead, children were investigated in depth using mixed methods incorporated in the design rather than a large random sample.

Design

The design of this study was not randomized, because of the large numbers of children required to identify children with DCD and those with co-occurring disorders from the population. Instead, the study adopted a targeted approach where teachers, after receiving information on DCD, identified children they thought had motor difficulties and those they considered typically developing.

A limitation is that this may have resulted in recruiting fewer girls. This may be due to gender bias or lack of staff awareness of motor problems in girls, with a possibility that they were under represented in the study. However, the design enabled an ecological approach with much more detailed contextual data collection possible for each child. It also allowed more in depth testing of each child across a range of associated characteristics and also a specific level of verbal and non-verbal IQ was available for each child. Thus two confounding variables were accounted for in the study.

Furthermore, the ecological design was more in keeping with the dynamical systems theoretical approach adopted to investigate the motor progression over

time. It therefore suited the study better than a large random sample group of children with DCD with a control group, as it facilitated a different type of analysis, encompassing both the child and his or her motor progression in context. Therefore, although the sample size was not sufficiently large to be able to generalize the statistical findings, the additional contextual information supplemented the findings of the main patterns of motor progression and facilitated theoretical implications to be drawn from the results.

Recruitment of participants

Recruiting a sample of children from mainstream schools was challenging, as schools are busy and have the pressure of following a prescriptive curriculum and external assessments. Physical space not in use and a slot in the school timetable to assess children proved difficult in secondary schools and resulted in fewer secondary children recruited to the study.

DSM5 criteria for DCD

The DSM5 criterion D requires ruling out other neurological conditions for a diagnosis of DCD. Zwicker & Michelson (2017) advocate examination by a paediatrician to ensure this, which was not possible in this study and so is a potential limitation. However, obtaining an early developmental and family history for each child helped to mitigate this.

Sample characteristics

There is a potential for recruitment bias as the majority of the children in the sample were recruited from one school in the UK, with an ASD unit attached. There was also an increased risk of a higher rate of co-occurrence of ASD and other developmental disorders. A comparative sample of 7-14 year old children randomly selected from a different area would support generalization of these findings to a wider population of children with DCD.

Attrition

The attrition rate over the two years of the project was 14.7% and led to some missing data at re-testing, but 85.3% of the sample was available for all the three data points. Missing data was not imputed to estimate missing scores, as experience and the other results showed such variability of performance. In addition, the attrition occurred across each of the three groups of motor ability, so minimising impact on the results.

IQ

The range of IQ score in this study was quite large and included three children with scores below 70, which has been the usual cut-off score for previous studies. However, DSM5 criteria for DCD diagnosis does not stipulate an IQ threshold, only that the motor difficulties must be in excess of those attributed to any learning difficulty. The group with the lowest motor ability also had the lowest mean IQ score and included one child with IQ of 55, another with IQ of 58 and another with IQ of 62, which brought the mean score down for this group, but all had motor problems in excess of those expected. However, even when these scores were removed for the group, the remainder of the group still had a lower mean IQ than either the group with moderate motor difficulties or the group of TDC. Several other studies have also found significantly lower IQ scores in groups of children with severe motor difficulties, consistent with the findings in this study.

The finding that these children did not show sufficient motor progression over the two-year period to change groups calls into question the role of IQ and motor learning. Previous literature indicated that IQ might have an impact on progression of motor performance. For example Green et al. (2008) found that the children with DCD with higher verbal IQ responded better to intervention and progressed better over time. Furthermore, studies of other children with neurodevelopmental disabilities (Snowling, 2008) have found that children with higher IQ tend to find ways to circumvent their difficulties. We also know that there is a higher incidence of motor difficulties in children with lower IQ (Keogh

& Sugden, 1985). Taken together with the findings from this study that the children with the lowest motor ability also had the lowest IQ may permit a different perspective.

If we interpret this from a dynamical systems theoretical stance and adopt an embodied cognition viewpoint we could suggest that the poor motor ability hinders cognitive development. Adolph & Kretch (2015) suggested that cognition builds on the foundation of perceptual knowledge. They quote Eleanor Gibson (1997) “Flexibility improves with learning and development. Expansion of the repertoire of available actions provides more opportunities for confronting novel challenges. Moreover, experiencing new environmental conditions provides opportunities to generalize old skills to new settings and to develop new solutions on the fly.” Thus, we are presented with a chicken and egg situation, because poor motor control limits exploration and limited experience of exploration limits opportunity for learning. Another interpretation could be that the children with lowest motor ability have lower IQ and a higher prevalence of co-occurring neurodevelopmental conditions because they have atypical brain development and less capacity for learning. However, this does not explain why some children, at the individual level, with severe DCD had both average IQ and co-occurring conditions. However, the concepts of IQ and of measuring it have long been contentious.

Obtaining consent/assent for children with low IQ and communication difficulties

Care was taken in this study to ensure that all the children understood the study information and consent procedure by help from a supportive adult, either a teaching assistant or parent. Future studies could use pictorial information to overcome comprehension difficulties for children or parents with literacy difficulties.

Associated characteristics

The extent of the role of co-occurring conditions and their AC on heterogeneity and motor progression in DCD is not fully understood. Visser (2003) advocated investigation of co-occurring conditions as a line of inquiry for heterogeneity, because the investigation of subtypes for DCD had proved inconclusive. The group with the lowest motor ability in this study also had the greatest prevalence of associated characteristics, a finding supported by other studies (Shoemaker et al., 2013; Kaplan et al., 2006) and so it is difficult to ascertain which had the greatest influence. A comparative population sample investigating children with pure DCD, ADHD, ASD and those with DCD with co-occurring conditions would be able to follow motor progression and investigate this.

A limitation to this study is that the group with the lowest motor ability had 90% of children with co-occurring ASD. The limited motor variability and lack of motor progress the group demonstrated over time could be attributed to ASD rather than severe DCD. However, a child in this group without ASD also displayed the same poor motor trajectory, suggesting that DCD was the culprit rather than ASD. This was also borne out by results from children who had ASD in the other motor groups, which had different, more favourable motor trajectories. Thus it is possible surmise that the high occurrence of ASD in this sample could be viewed as a strength of the study. However, this would need to be verified in larger studies with more children with severe DCD and no ASD.

Another potential limitation to this study is that DCD is known to co-occur with many different conditions, such as anxiety, Tourette's, dyslexia and dyscalculia, which were too numerous and not screened for in this study. There is a possibility that they could impact on the child's participation in extra curricular PA, but less likely to impact on the motor results.

Over time

Methodological issues have made comparison of studies difficult and so not enough is known about how the children with DCD progress over time. Many studies used different motor cut-off points to identify and categorize the children

and others did not clarified how DSM criteria were met. Studies also used different methods to compare the children, for example Green at al. (2008) chose to categories according to perceptual deficits and others have used presence of co-occurring disorders. The length of follow up also varies substantially, from a year and a half to over 15 years, and the number and frequency of data points also varies considerably. The choice of method of analysis is widely different across studies and linear and non-liner methods have different emphasis and are likely to lead to different conclusions. Group comparison using GLM versus individual data can also have a different emphasis, as this study has shown. Even how change in motor ability is determined and measured differs, for example, the use of different motor tests (MABC, MABC2, MAND, Bruininks), and even within the same test the use of different levels of significant change. For example, LDD (Green et al, 2008) or MID (Wuang et al., 2012) making comparison across studies difficult. The theory underpinning the study can also make a difference in how the data is interpreted. For example, intra individual motor variability can be viewed either as 'noise' or as important data about the motor trajectory. We have also seen that development is a bidirectional process between the child and the environment and so the context in which the child develops over time becomes an important part of the analysis.

A potential limitation of this study is the length of follow up (2 academic years) which gave a brief window on child motor development. Future studies could increase the follow up time to obtain a more comprehensive picture of the motor stability and change.

Age range

This study chose participants 7-14 years old at the start of the study. A limitation is that comparison with a narrower age band would ensure comparison of similar motor tasks and types of participation in PA. It would also remove any motor test ceiling effects and use only one age band in the motor test with exactly the same test components. The effects of maturation of the nervous system is more apparent in older children and leads to better motor

skills; however, the older children did not improve any more than younger children. Moreover, since MABC2 is a standardised test, age would not impact the motor results, but would be more likely to impact participation in PA.

Family context & attitude

Bronfenbrenner's bio ecological model provided a useful framework with which to explore the child's context. The results showed that there was no difference in SES between the groups and all had a similar physical environment, yet very different motor progression. However, on the individual level, family attitude towards PA and the level of encouragement and support made a difference to the level of participation in PA of the child, irrespective of their level of motor ability. The role of culture is also important. Adolph & Hoch (2019) propose that motor development is encultured, social interactions are the impetus and caregiver support may constrain motor behaviour by structuring the physical environment in which motor skills develop. Cultural norms in turn influence social interactions, child rearing and home environments provide the backdrop for motor skill acquisition. This may account for the very different experiences of the children, despite their motor ability. It may also account for the under diagnosis of girls with DCD, as girls are not expected to engage as actively in physical play as boys. This may be a possible limitation in this study as cultural gender influences expected roles for girls, which could influence their self-perception in tools such as the CSAPPA. This could explain the self-perceptions of the girls in the moderate group in this study, who improved their motor performance but not their self-perceptions of their adequacy, enjoyment and predilection to take part in PA over time.

7.9 Theoretical and clinical implications from motor change over time

The findings from this study indicate that the children with DCD in the lowest 5th percentile of motor ability represent a group with distinct characteristics, which is supported by other recent studies (Schoemaker et al., 2013; Flapper &

Schoemaker, 2013). As a result they represent the group at the greatest risk of multiple adversities, because they are more likely to have AC and lower IQ (Gillberg, 2010), which puts greater strain on the families. Moreover, importantly, the findings from this study revealed that the motor characteristics for this group persisted over time. However, this was in contrast to the findings of Green et al. (2008) who reported improvement in motor performance for this group. However, that study differed in two important ways to the present study. First it was an intervention study, so the change noted could be attributed to the intervention that the children received and second it used a different method for measuring motor change. Motor change was acknowledged as ≥4 MABC total score points, (referred to as least detectable difference, LDD) as opposed to the present study, which used ≥10 MABC2 total score points and the MABC2 traffic light categories to indicate change. It is therefore possible that the improvement reported in that study might not register as change in the present study.

Moreover, previous longitudinal studies that categorized groups by initial motor severity have also found that children with DCD in the lowest 5th percentile of motor ability have relatively stable poor motor performance and ongoing motor difficulties over time. For example, Pless et al. (2002) and Cantell et al. (2003) both used DSM IV criteria to identify DCD and determined motor change as a change in MABC category, found similar results, that those with the poorest motor performance had continued difficulties over time and support the findings of this study.

However, unlike some previous longitudinal studies, the lack of improvement in motor performance in the present study could take account of context, including SES, presence of co-occurring characteristics and children's IQ as well as comparison with a group of typically developing peers. This therefore adds further support that this group differs both from typically developing children and from those with milder motor impairment over time, by confirming that the difference could not be attributed to IQ or SES. This poses questions about the

cause of the underlying difference and why the groups presented such different intra-individual variability over time. How should we interpret variability?

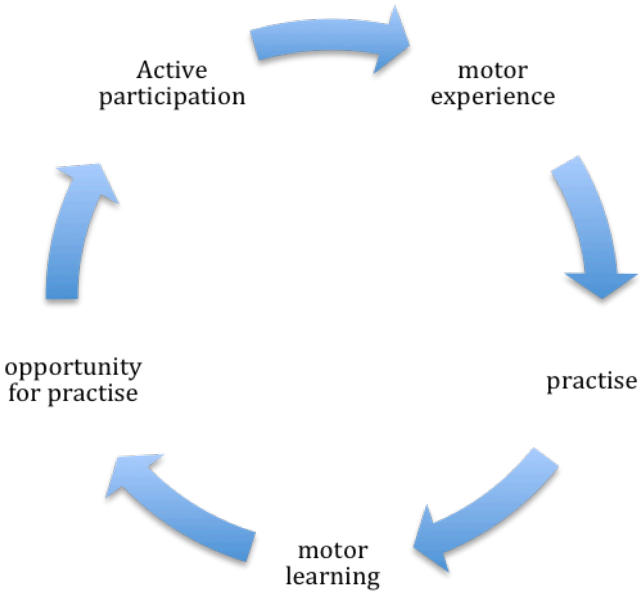
Viewing motor development from a dynamical systems perspective may permit a plausible explanation. The children with DCD with the lowest 5th percentile of motor ability demonstrated a lack of variability in their motor performance over time. Their poor balance and motor coordination, not conducive to allow them to unfreeze sufficient degrees of freedom, made it harder to adapt to new tasks or environments. It is possible that this in turn inhibited their active engagement with sufficient motor activities for them to learn new motor skills or accumulate the benefits from enhanced active participation. Indeed, this group had the lowest reported rates of participation in PA. The restricted movement repertoire further restricted new learning opportunities in motor and possibly social and other domains.

Paradoxically, researchers usually consider decrease in intra individual variability to be a sign of skilled performance and control as decrease in variability usually accompanies more consistent, accurate and economical performance. Indeed, the MABC2 results from the children who were without motor impairment were expected to reflect this. However, Adolph et al. (2014) warned that the endpoint of development is not elimination of variability, as intra individual variability only represents error for particular skills measured in particular ways. Adolph et al. (2014) cautioned that the paradigm in which basic motor skills are studied, in part, favours this conclusion. This is because the environment, the task constraints and participant's bodies are held constant and so a reduction in variability is presumed to be important. However, they argue that the role of variability is not so simple. This may well have a bearing on the results of motor testing in the present study because, although the tasks and environment remained constant, all the children's bodies grew and their opportunities for motor experience changed over the two-year period. This may account for the observed variability recorded across all children. However, the extent and nature of the variability differed between groups.

The presence of consistently low motor scores of the group of children who score in the lowest 5th percentile on the MABC2 indicates a lack of the appropriate strategies to gain from experience of every day activities and therefore contributes failure to adapt and develop new strategies. This may result in a limited repertoire and the children are thus less likely to tackle a real time problem with a satisfactory solution, which in turn restricts movement experience. In this sense the decrease in variability is seen as unhealthy or atypical development. Fig. 7.1 is a diagrammatic representation of a cycle of motor learning through experience and opportunities for practice in a child with typical motor development.

As previously mentioned, Adolph et al. (2014) explained that an increase in intra individual variability serves as an exploratory function, because sufficient experience in a variety of settings allows children to adapt movements simultaneously to changes in the body and the environment. In the course of coping with a task new different strategies arise and present more ways to tackle a problem, which increases the probability of selecting an appropriate solution. This opportunity is severely restricted in the children with DCD in the lowest 5th percentile of motor ability. Adolph et al. (2014) suggested that opportunities for learning variable movements in action create a variety of strategies, which in turn generate information about the self, the environment and, importantly, relations between them. Therefore, children with DCD in the lowest 5th percentile of motor ability miss out on many learning opportunities and are further disadvantaged by fewer opportunities to develop strategies and thereby develop an unhealthy cycle for motor proficiency.

Figure 7-1 Sufficient experience for motor learning for typically developing children



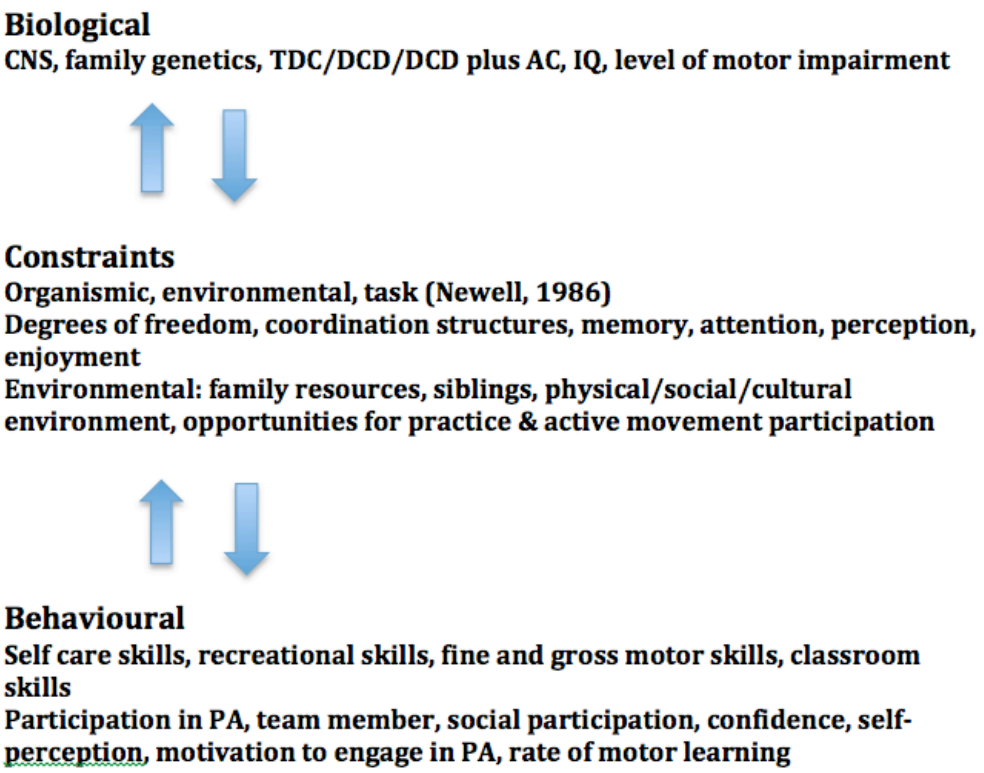
Schmidt & Wrisberg (2000, p241) sum this up by quoting Bernstein (1967, p134) “The process of practice towards the achievement of new motor habits essentially consists in the gradual success of a search for optimal motor solutions to the appropriate problems. Because of this, practice, when properly undertaken, does not consist of repeating the means of a solution to a motor problem time after time, but in the process of solving this problem again and again“

Children in the lowest 5th percentile appear to demonstrate that they are unable to benefit from normal practice, as they fail to learn the problem solving necessary to develop appropriate movement strategies and merely repeat the same solution time after time leading to lack of variability (stable) poor motor performance. Schoemaker and Smits-Engelsman (2015) argue that this is the case for DCD. They explain that when children with DCD were tested after participating in either intense play versus specific neurodevelopmental task training (NTT) with therapists, children with DCD improved significantly more and had more generalized learning after specific training with NTT. They

concluded that more effective motor learning for children with DCD was established with NTT, where the children had been provided with explicit instruction and feedback in task orientated intervention. However, more research is required, as only one study has supported this at present.

Hadders-Algra (2010) advocated investigation of variability of motor performance to help discriminate children with typical from those with atypical motor development. She suggested that human development is characterized by the development of adaptive variability. Atypical children show limited variation and an impaired variability to task specific requirements, and therefore require much more practice to learn motor tasks (Hadders-Algra, 2010). Children with DCD in the lowest 5th percentile appear to have this impaired variability that corresponds to atypical development. Moreover, the higher prevalence of co-occurring characteristics and of first-degree relatives with developmental conditions in the 5th percentile group of children in this study appears to indicate they may have a possible genetic difference prompting a gene-environment interaction expressing as atypical motor development. This could infer a different underlying aetiology to the motor difficulties encountered by this group compared to the children with moderate motor difficulties. Future research may find this a fruitful line of inquiry. However, due to the plasticity of the CNS this does not necessarily infer a one-way developmental influence from underlying biological substrates, but could also include the influence of the environmental context.

Figure 7-2 Morton's model incorporating study findings (adapted from Sugden & Wade, 2013)



Sugden & Wade (2013) offered a modified Morton model to illustrate this in a dynamic system. This offers the potential to positively influence development by intervening and adapting motor tasks and the environment in order to permit a child's positive experience of active motor engagement and thereby promote learning opportunities otherwise denied to them. Motor scores alone do not provide sufficient information about motor development and the acquisition of motor skills in DCD, indeed Albaret & de Castelnau (2007) suggested that details of a child's context and impact on everyday life are also required. This study used Bronfenbrenner's bio ecological framework to provide another useful lens through which to view some of these contextual influences and examine the results in light of these. This lens was particularly helpful when considering some of the factors common to those children who were able to successfully

participate in physical activity and a further modification of Morton's model is shown in Fig. 7.2.

In contrast the children with moderate motor difficulties (6-16th percentile) all appeared to resolve their motor difficulties over time. Interestingly, Green et al. (2008) also found that many of the children identified with moderate motor difficulties in their study resolved without intervention over time. We can infer that they were able to adapt and improve their motor repertoire and learn from adapting to changes in their bodies, task or environment to widen their repertoire so that they became indistinguishable from their typically developing peers over time. However, the large degree of variability the group exhibited in this present study may indicate a lack of stability in their performance. For example, on the 4th data point a child's motor performance had reverted back to the 16th percentile perhaps indicating that the adaptive strategies had not become automatic so were not 'relatively permanent'. This could be tested with studies following children over more data points and longer periods. Previous studies (Pless et al., 2002; Cantell et al., 2003) have also found that this group of children can have variable results, with some improving so that they are indistinguishable from their typically developing peers, whilst others deteriorate over time. Even intervention studies have found a high level of variability. For example, Sugden and Chambers (2006) found that, despite children with DCD improving motor performance following intervention, they reverted back to low levels of performance once it had ceased and Green et al. (2008) found that some children with DCD had worse motor performance following intervention. So what can these observed differences in variability tells us about DCD?

Variability is inherent in biological systems as it ensures survival by having the flexibility to adapt to changes in order to optimize success, whilst maintaining optimal stability and performance (Smith & Wade, 2015). Furthermore, reduction in variability is seen as tantamount to a loss of flexibility to respond to changes in the demand of the environment (Smith & Wade, 2015). The lack of motor progress seen in the children with DCD in the lowest 5th percentile appears to relate to this lack of adaptability and flexibility in motor response.

They did not exhibit variability in performance, but maintained their low scores over time with impaired function.

On the other hand, the children with moderate motor impairment, who started in the 6-16th percentile of motor ability, but improved their performance over time to achieve typical motor performance exhibited wide variability. They showed that they could adapt and develop better motor skills, but that they were not necessarily stable, as displayed by the score reverting back to a lower motor category over more time. Here linear analysis with GLM did not tell full picture as it removed the temporal organization and masked the pattern. Smith & Wade (2015) assert that linear measures limit the explanation of performance variability, as they contain no information on the time-evolving nature of performance variability.

The majority of children who started with typical motor performance remained in this category over time, despite a range of patterns of progression and decrements, and maintained the stability of functional performance. The variability and inter-individual differences that they displayed achieved success and must have achieved an optimal level of variability and adaptability to maintain this level of performance over time. It is of interest that two of the three children who moved into the impaired range of motor ability over time also had additional problems of ACs and therefore could not be counted as TDC and the third had an unknown early history. We can therefore assume that TDC were able to manage optimal stability and performance, as their variability equated with flexibility, for managing constraints over time. Smith & Wade (2015) suggest that skilled performance demonstrates flexibility and adaptability, which equates with stability, and call this "good variability" because it is essential for consistent control. They explain that no two instances of a skilled action are identical because they are capable of managing changing environmental contexts.

Therefore by using both linear and non-linear methods for analysis in this study a more detailed picture could be compiled about the nature of the differences in change over time. The linear methods demonstrated group differences at base line and over time between children with different motor ability. However, it was the non-linear analysis that was able to demonstrate the importance of inter and intra-individual differences and point to some possible contextual influencing factors in progression and participation for children with DCD.

7.10 Conclusion

This prospective longitudinal study investigated the nature of DCD by examining the characteristics of children with and without DCD by classification of their motor performance ability. Careful identification of the children with DCD with DSM5 criteria ensured that the focus was on DCD. Furthermore, distinguishing between the children with moderate motor impairment (6-16th percentile MABC2), severe motor impairment (≤5th percentile MABC2) and TDC (≥25th percentile MABC2) permitted separate investigation of characteristics and their motor progression.

The first important finding indicated that the children in the lowest 5th percentile of motor ability were a group with distinct characteristics. Group comparison revealed potential biological differences, as the children with severe motor impairment had characteristics distinctive from the other groups. They not only had poor motor performance across all domains, but also had lower mean IQ scores than the children with moderate motor impairment (6-16th percentile) and TDC (≥25th percentile). In addition, they were more likely to have two or more associated characteristics of other developmental disorders, particularly ASD and ADHD and a first degree relative with a developmental disorder. This indicated that they were at more serious disadvantage to start with.

To my knowledge this is the first study that investigated whether the motor characteristics of these different groups were stable or changed over time that

also screened for associated conditions and IQ. The second important finding was that the children in the lowest 5th percentile did not change motor performance ability over time. Group comparison with GLM identified that the groups progressed differently over time. However, individual analysis allowed investigation of inter and intra group differences and revealed that children with severe motor impairment had stable motor progression and limited variability. They remained stable over two academic years, whereas the groups with moderate impairment and TDC showed more variation.

The study used an ecological design and was therefore able to investigate the children's context. The third finding was that despite having similar opportunities at school, physical environment, socio-economic status and self-perceptions about their physical ability to the children in the other two groups, the children in the lowest 5th percentile did not improve their motor performance over time. Some of this group even actively participated in sports and PA for leisure, yet still did not improve motor performance and remained in the lowest category over time. Importantly, the group with moderate impairment all improved over time to the level of typical motor performance in the same time period, whereas the severe group did not change.

The motor progression was viewed from a dynamical systems approach and this study highlighted the role of 'good' and 'bad' variability in motor development. This is emerging in the literature as an indicator for the presence or absence of atypical development. For example, children who can vary their motor performance and adapt to environmental constraints develop better motor skills, whereas lack of variability reduces the available responses repertoire and successful performance is less likely. The children in the lowest 5th percentile demonstrated lack of variability and lack of motor skill mastery, despite similar school experience and opportunity. This indicated that experience alone was not sufficient to improve their motor performance. Even at the individual level, the children who participated in extra curricular PA and had high self perceived motor competence and strong parental encouragement,

did not improve sufficiently to move out of the lowest 5th percentile. They were unable to adapt and learn by experience alone, indicating atypical motor development and suggest that specific training is required if they are to improve motor performance and generalize the learning. There is emerging literature supporting this view (Schoemaker & Smits-Engelsman, 2015, Preston et al., 2016) but more research is required to test this hypothesis.

On the other hand, the group with motor ability at 6-16th percentile all improved over the same time period without intervention, but demonstrated a high level of variability in motor performance over time. All improved and changed motor category on MABC2 by the third data point. However, some children that were tested a fourth time had subsequently deteriorated. This indicated instability and showed that the motor learning had not reached the 'relatively permanent' stage. The inference drawn from this is that motor learning took place to improve motor performance, but that it was not stable. It also shows that with the same opportunities at school, physical environment, socio-economic status and self-perceptions about their physical ability, they improved their motor performance over time. This indicated that experience and active engagement in PA was sufficient to improve motor performance over time without specific training. However, a question still remains about their retention of these skills long term and should be studied further.

The typically developing children, those ≥25th percentile of motor ability, also demonstrated variability in motor performance over time, but of less magnitude than the moderately motor impaired group. The majority remained in the typical motor development range over time. With the same opportunities, experience at school and physical environment they maintained typical levels of motor performance, indicating that these alone were sufficient for the acquisition and retention of age appropriate motor performance over time.

Therefore a difference in motor learning and skill acquisition between the children in the lowest group of motor ability and groups of children with different

levels of motor difficulty is indicated. The role of practice and experience in motor learning may well be different for children with the lowest 5th percentile of motor ability and that this warrants further investigation. It also has implications for policy, as the children with motor ability in the lowest 5th percentile will require careful screening for other developmental disorders and specific intervention if they are not going to be further disadvantaged.

A third important finding was that the children's self perception of their adequacy, predilection and enjoyment of PA were not dependent upon their motor performance ability and was unexpected. There was no difference between the groups in self-perception of adequacy, enjoyment and predilection to participate in PA, yet in general, the children with motor impairments participated less in PA. However, analysis at individual level revealed important differences for participation in extra curricular PA for the children with motor impairment. The findings that some children with both moderate and severe motor impairment enjoyed and participated in PA indicated a positive signal for future intervention programmes.

A fourth finding was that the children in the lowest 5th percentile of motor ability often faced additional barriers to participation in extra curricular PA, such as a sibling or parent with a developmental disorder, family financial pressures and lack of transport. The Bronfenbrenner framework facilitated a more in depth analysis of ecological reasons behind participation and non-participation in PA for children both with and without motor difficulties. The ecological study design permitted analysis both at the group and individual level, which facilitated a deeper understanding of the dynamic interaction between children and their context and gave insight into some influences in their development. This was important, as a dynamical systems approach to motor development requires greater understanding of these dynamic interactions. The findings have important policy implications, as additional parental support through inclusive schools or community services can help alleviate some of the barriers to

participation and avoid the secondary consequences associated with non-participation in PA.

The fifth finding came from data from interviews with the children across all motor abilities. This gave further insight, from their perspective, and highlighted what they found to be supportive environments to enable participation in PA. Themes that emerged were that they enjoyed PA, had access to local amenities, had supportive parents who valued PA, their parents participated in PA themselves and had transport. This also has policy implications for community services, parents and teachers to help improve participation in PA for children. This is important, since active self-generated movement is crucial for motor development from a dynamical systems perspective. Therefore, an inclusive environment that facilitates this for children with the most severe motor impairment is imperative, given their additional problems.

Finally, the broader question of participation for children with DCD should be considered. This study demonstrated that children with DCD clearly have impairment, but the findings also indicated that participation in PA was possible, even for children with severe motor performance difficulties. However, they also crucially indicated that the children's ecological context was a vital part of their successful participation. The ICF emphasises participation as the desired outcome of intervention and so challenges both researchers and clinicians to consider appropriate outcome measures and study design that capture this important issue. This will help the future design of inclusive and supportive environments for children with DCD and other motor impairments.

Future directions

The study should be repeated with a larger cohort of children to recruit more children in each category, especially those with pure DCD, to investigate whether the characteristics found in the lowest 5th percentile are consistent with the results from this study.

Knowledge transfer of information of the positive impact of supportive environments to facilitate participation in PA for children with motor difficulties should be disseminated to schools, parents, therapists and community services. The outcome of this should then be evaluated.

A future study should investigate the difference in motor learning and generalisation of motor skills between children with severe DCD (lowest 5th percentile) and those with moderate DCD (6-16th percentile) following a cross over intervention trial using a specific training method.

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Appendix 1 Ethical approval

Performance, Governance and Operations
Research & Innovation Service
Charles Thackrah Building
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UNIVERSITY OF LEEDS

Vicky McQuillan

School of Education

University of Leeds

Leeds, LS2 9JT

AREA Faculty Research Ethics Committee

University of Leeds

3 October 2019

Dear Vicky

Title of study: **The progression over time of profiles of children with Developmental Coordination Disorder (DCD)**

Ethics reference: **AREA 12-121, response 2**

I am pleased to inform you that the above research application has been reviewed by the ESSL, Environment and LUBS (AREA) Faculty Research Ethics Committee and following receipt of your response to the Committee's comments, I can confirm a favourable ethical opinion as of the date of this letter. The following documentation was considered:

Document	Version	Date
AREA 12-121 response2.docx	1	20/01/14
AREA 12-121 Dec Final ethical consent and information sheets.docx	1	09/12/13
AREA 12-121 Ethical review form final version.doc	1	12/06/13
AREA 12-121 Interview schedule.docx	1	12/06/13
AREA 12-121 Child Information sheet.docx	1	12/06/13
AREA 12-121 parent information sheet Movement development and children.docx	1	12/06/13
AREA 12-121 Appendix 2 parent consent form.docx	1	12/06/13

Committee members still had concerns about the information leaflet for children who are only 8 years old and urge you to further adapt the information leaflet for younger children. It should be much more user friendly and talk directly to the child. Reviewers suggested showing it to a primary school teacher and perhaps carrying out a pilot with some children of a similar age before it is used.

Please notify the committee if you intend to make any amendments to the original research as submitted at date of this approval, including changes to recruitment methodology. All changes must receive ethical approval prior to implementation. The amendment form is available at http://ris.leeds.ac.uk/EthicsAmendment.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited. There is a checklist listing examples of documents to be kept which is available at http://ris.leeds.ac.uk/EthicsAudits.

We welcome feedback on your experience of the ethical review process and suggestions for improvement. Please email any comments to ResearchEthics@leeds.ac.uk.

Yours sincerely

Jennifer Blaikie

Senior Research Ethics Administrator, Research & Innovation Service

On behalf of Dr Andrew Evans, Chair, AREA Faculty Research Ethics Committee

CC: Student's supervisor(s)

Appendix 2 Study flyer

The project also includes a group of children referred to clinic that will also be followed up in conjunction with Woodview Child Development Centre

Children with movement difficulties in Schools

Up to 5% of schoolchildren have difficulty with motor coordination that is not due to any medical condition. This can seriously interfere with daily life at home and school. We have a project to investigate it and would like to invite you to take part.

2014 Project

Vicky McQuillan
PhD candidate
University of Leeds

University of Leeds
School of Education
Hilary Place, Leeds

Professor David Sugden
University of Leeds

University of Leeds
Dr Mary Chambers & Dr Ruth Swanwick

CONTACT:
vickym@liv.ac.uk

It often goes undiagnosed and yet is a long-term condition remaining throughout childhood and into adulthood often causing difficulty with handwriting, tool use, ball skills and physical activity. It is called Developmental Coordination Disorder (sometimes known as dyspraxia). It can have a negative impact on a child's confidence and is frequently accompanied by other difficulties such as poor attention, reading or language difficulties and problems with social interaction.

Without appropriate identification and intervention the children are at risk of being unable to participate in physical activities with their peers, also risk obesity, psychological distress and are more vulnerable to bullying. However, with effective identification and management many of the difficulties can be addressed and the secondary consequences avoided.

VICKY MCQUILLAN M ED, DIP COT
Principal Investigator
University of Liverpool, School of Health Sciences

The aim of this project is to identify two groups aged 8-16 years. One group suspected by their teachers of having movement difficulties and the other group with no movement or learning difficulties (typically developing). To help us understand factors in their development, the children will be assessed for motor and associated characteristics and then their motor development and progress will be monitored over 20 months (3 contacts). The project has ethical approval from Leeds University ethics committee.

Initially we will send a letter inviting parents and their children to take part in the project. Those who agree to take part will be invited to complete short questionnaires and the children (if they agree) will be invited to take part in activities that assess verbal, non-verbal ability and motor ability and a short questionnaire about enjoyment and participation in physical activity. They will be reassessed every 6 months.

EACH CHILD PARTICIPATING:
Will receive a short summary of their results and the parents and teachers of any children identified with difficulties will be given written advice.

Appendix 3 Letter to head teachers and information for teachers

School of Education

University of Leeds

Hilary Place

Leeds

Dear Headteacher,

I am an occupational therapist and previously worked in the NHS at Woodview Child Development Centre in Widnes before taking up my post at Liverpool University.

I am currently researching a childhood condition called developmental coordination disorder (DCD), also known as dyspraxia. It is of great significance to teachers because it is so commonly found in the school age population but so little understood and yet can impair participation and progress at school.

I would like to invite you and children attending your school to participate in the project, which has received ethical approval from Leeds university research ethics committee.

The aim is to invite parents and their children to take part by letter and then recruit children aged 8-14 years old who have been identified by their teachers as having possible coordination difficulties (may manifest as poor handwriting, poor balls skills, difficulty with tools or equipment) and another group of children without coordination difficulties or learning difficulties for comparison. Research so far has very little information about how children with the condition change during adolescence and we suspect that girls may well be under represented.

We are therefore including both primary and secondary age children in the project.

My team and I will assess all the children who consent to be involved using questionnaires and a standardized movement assessment which present tasks as a series of games. Their parents will also be asked to complete short questionnaires. The children will be reassessed every five months to document change (on 3 occasions) and a small sample of children and parents will be invited to an interview about their experiences. All results will be anonymous and kept confidential.

The results will inform us about the factors associated with change in movement ability and the impact on participation. We will run workshops for professionals and parents to share our findings and help inform future intervention. I am happy to meet you and your staff to explain the research further.

Thank you for taking the time to read this and I look forward to hearing from you.

Yours sincerely,

Vicky McQuillan M Ed, Dip COT vickym@liv.ac.uk

Instruction for teachers:

- Introduce the research study explaining the importance of investigating how children's movement skills impact on progress and participation in daily life (see research project flyer "Children with movement difficulties in schools")

- Explain the need to investigate some children who have difficulty with motor skills as well as some children who do not display any difficulty

- Identify any children that you suspect may be encountering difficulty with motor coordination (see leaflet "secondary school children with possible DCD")

- Identify children without motor coordination difficulty and who also do not have any special educational needs and try to **match as closely** as possible to the same year group, age and sex as possible.

- Obtain parental consent and consent from the child to participate in the study

- Collect consent forms to return to the researcher

- Parent questionnaires will then be distributed via school

- The researcher can be contacted by email to answer questions that the parents may have. It is possible to arrange to be available for a drop in session at school if parents or teachers want additional information.

- The researcher will then arrange to collect the questionnaires and arrange a convenient time to carry out the assessment with the child

- A short summary report will be given to each parent to share with their child

- The child assessment will then be repeated the following two terms

- The school will receive a copy of summary of the projects findings and staff will be invited to workshop to discuss the findings and potential implications.

Children with possible Developmental Coordination Disorder (DCD) in secondary school:

Children with DCD have an unexplained difficulty with the development of their motor coordination, i.e. their difficulties cannot be attributed to a known medical condition, such as cerebral palsy. Either their fine motor coordination or their gross motor coordination, or even both, can be affected.

Children who have reached secondary school without receiving a diagnosis for DCD may well have covered their difficulties with a range of strategies that are effective in primary school and a less demanding environment, but this starts to break down as more demands are expected.

Sometimes the symptoms of DCD may only manifest as increased pressure on speed and volume of writing occurs. Teachers might notice some of the following:

- Very slow handwriting and difficulty completing timed work.
- Disorganized work and very untidy handwriting
- Good verbal ability but paucity of written out put.
- Avoidance of P.E. and if they do attend, they show poor ball skills and difficulty orientating the body to equipment or positioning themself on the sports field. They may be much slower at getting changed.
- Clumsy manipulation of equipment and frequent spills in technical subjects and science labs.
- Difficulty organizing their time and or belongings.
- Difficulty opening packaging e.g. items in a packed lunch
- Girls and boys may react to difficulties differently; often girls tend to withdraw and keep 'under the radar' and tend not to present behaviour problems at school.

The benefits of identifying DCD

1. Assessment and correct diagnosis acknowledges the children's difficulties, promotes self-understanding and helps the adults supporting them to advocate for them and alleviate some of the frustration.
2. It reinforces that the child is not at fault or 'not trying'
3. Task analysis and appropriate adaptive strategies can be adopted to help the child master every day activities and participate
4. Alternative forms of recording written work and exam concessions can be adopted if appropriate to enable the children to reach their potential
5. In more severe cases, referral to therapists for direct intervention may be required

Appendix 4 Study information sheets and consent forms

Parent information

Movement development and children

Vicky McQuillan David Sugden Mary Chambers

Dear Parent,

We are working with children, some of whom have movement difficulties, and we are interested in how they cope with movement activities that they require for everyday life. We are asking for support to work with your child and help you make a decision on permission. We are outlining the study, what your child will do and what we will do with the results.

The results of this work will inform us about patterns of movement development and the collective results will aid other children with movement difficulties who are showing similar characteristics both in this country and internationally.

Background to the project:

Children who experience movement difficulties, but with no apparent medical reason may meet the criteria for a condition called developmental coordination disorder (DCD). Children with DCD show great variety in their motor development. This impacts on their lives in areas such as mobility and balance leading to reduced participation in everyday activities and recreation. It can also impact on handwriting and tool use. Many children with DCD also have associated difficulties, for example with attention or learning to read, whilst others have no difficulties.

Aims of the project:

1. To identify a group of children who may be at risk of DCD or have DCD and those who do not.
2. To profile in detail these children to identify their movement capabilities and any associated characteristics over a period of 21 months.
3. To ascertain how these capabilities and characteristics influence activities of daily living, academic progress and enjoyment of physical activity.
4. To examine how they develop and change over time.
5. To examine which patterns of movement difficulty and which characteristics hinder progress.

What the children, teachers, parents and researchers will do:

1. Parents will be given short questionnaires asking about their children's movement abilities and about their child's family history and communication.

2. Children will be given an assessment of their motor skills by using the Movement Assessment Battery for Children (MABC2) (approximately 40 minutes). They will also be given an assessment of their verbal and non-verbal ability (KBIT2). They will also be asked to complete a questionnaire about their enjoyment of physical activity (approximately 10 minutes). Parents will be given a short summary of results and if any difficulties are identified they will be provided with a information sheet, details of where to seek support and an appropriate pathway of referral.

3. We would like to interview a small number of teachers, parents and children to ascertain which types of activities the children may experience difficulties and their views (approximately 30 minutes). We would like to interview a small number again over the 21 months (maximum of 3 times). You will be given the opportunity to indicate whether you would prefer not to be contacted for an interview on the consent form.

4. After 6-8 months the all the children will be given another assessment of their motor skills and a questionnaire on their enjoyment and participation in physical activity and this will be repeated after another 6-8 months (a maximum of 3 assessments).

5. From the results of this investigation and from the research, and professional literature on DCD and motor learning, we will gain better understanding of how children with DCD progress, and what helps or hinders progress. From this recommendations will be made to help with the planning of appropriate interventions for children with DCD and associated characteristics.

6. A short summary of results will be given to the parents of each child who takes part in the study. Finally, workshops will be run by Vicky McQuillan, Professor David Sugden and Dr Mary Chambers at the end of the project for parents and professionals to share the findings and plan a way forward.

Vicky McQuillan January 2014

PhD candidate

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Parent consent form

Please circle the appropriate response **Yes or No**

- I confirm that I have read and understood the information letter dated September 2013 explaining the research project. **Yes No**

- I understand that our participation is voluntary and that we are free to withdraw at any time without giving any reason and without there being any negative consequences. In addition, should I wish not to answer any particular question or questions, I am free to decline. **Yes No**

- I understand my responses will be kept strictly confidential. **Yes No**

- I agree for the data collected from me, and my child to be used in relevant future research and for our data to be held securely in a data archiving facility. This includes audio extracts for teaching and conferences/seminars **Yes No**

- I understand that I am free to withdraw from the study at any time, but that any data already collected and anonymised will remain in the study and contribute to the overall results **Yes No**

- I confirm that I give my permission for the researcher to approach my child **Yes No**

- I agree to being contacted for an interview **Yes No**

- I agree to take part in the above research project and will inform the lead researcher should my contact details change **Yes No**

Vicky McQuillan
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January 2014

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Child information sheet

Movement development and children

Vicky McQuillan David Sugden Mary Chambers

Invitation

You are being invited to be part of a research study. This research study tries to understand how children get better at movement skills as they get older. These are skills such as balance, throwing and catching and handling small objects. These skills are needed to do every day activities.

It is up to you if you want to take part in this study. Even if you agree now to be part of the study you can change your mind later. No one will be annoyed with you if you choose not to be part of the study.

Why are we doing it?

Some children have difficulties with movement skills and this stops them doing some of the things that they want to, even some things that other children do not find difficult.

This study is trying to find out which children have difficulty with movement and the type of challenges they have. It will follow how the children change over time to compare with children who do not have movement difficulties. This will help us to understand how children get better at movement skills and explore some ideas that may help the children who have difficulty with movement.

What will happen?

If you agree to be in this study, a researcher will come to your school once a term for about an hour on three different occasions. Each visit you will be

asked to do activities involving balance, throwing, catching and drawing and answer some questions on whether you enjoy or take part in physical activity.

If you decide that you do not want to continue in the study you can stop at any time, but the information that we have already collected will stay in the study.

A small number of children will be invited to have interviews about their movement experiences. If you would rather not be asked to an interview then please circle **No** on the attached form.

Who is doing the study?

Vicky McQuillan, other therapists and therapy students will come to your school.

Who will know I am in the study?

Only your parents, teachers and the researchers will know you are in the study. When the study is finished Vicky will write a report about what has been learned. This report will not say your name or that you were in the study.

When do I have to decide?

It would be a good idea to discuss your decision with your parents. Then let Vicky know if you want to take part in two weeks time.

If you would like to be part of the study then put your name at the end of the attached form.

Thank you for taking the time to read this and for your help.

Vicky McQuillan PhD candidate
School of Education
University of Leeds
Leeds LS2 9JT

January 2014

Email: edvam@leeds.ac.uk

(Adapted from Child & Family Institute Canada, March 2010, www.CFRI.Ca)

Child consent sheet

Movement development and children

Vicky McQuillan David Sugden Mary Chambers

Please circle your answer **Yes or No**

- I have read and understand the information letter dated September 2013 explaining the research project. **Yes** **No**

- I understand that I am free to stop at any time without giving any reason and without there being any problem. In addition, if I wish not to answer any particular question or questions, I am free to not to. **Yes** **No**

- I understand my responses will be kept strictly private. **Yes** **No**

- I understand that I am free to leave the study at any time, but that any information already collected will stay in the study and contribute to the overall results **Yes** **No**

- I agree to being contacted for an interview **Yes** **No**

Vicky McQuillan
PhD candidate
School of Education
University of Leeds
Leeds LS2 9JT

Email: edvam@leeds.ac.uk

January 2014

Child interview information

My name is Vicky McQuillan. I am an occupational therapist working in a university. I am doing research about how children develop their movement skills.

I would really like to hear about you and your experiences with movement in every day life, for example, at home and school.

Our talk would be in private but your ideas will help us to understand more about how children develop movement skills in every day life. I would like to come back to hear your ideas again after the next school term and then one more time the following term (3 times in total).

You can ask for the interview to stop at any time. It will not take longer than an hour.

You can say yes or no. It is up to you whether you take part and nobody will be annoyed with you if decide that you do not want to take part.

If you would like to take part in the study by talking to me please sign the attached form and return it to school.

If you want to know more information about the project please contact me at the address below.

Thank you for taking the time to read this and for your help.

Vicky McQuillan
PhD candidate
School of Education
University of Leeds
Leeds LS2 9JT
Email: edvam@leeds.ac.uk

January 2014

Child interview consent sheet

Movement development and children

Vicky McQuillan David Sugden Mary Chambers

Please circle your answer **Yes or No**

- I have read and understand the information letter dated January 2014 explaining the research project. **Yes** **No**

- I understand that I am free to stop at any time without giving any reason and without there being any problem. In addition, if I wish not to answer any particular question or questions, I am free to not to. **Yes** **No**

- I understand my responses will be kept strictly private. **Yes** **No**

- I understand that I am free to leave the study at any time, but that any information already collected will stay in the study and contribute to the overall results **Yes** **No**

- I agree to being contacted for another interview **Yes** **No**

Vicky McQuillan
PhD candidate
School of Education
University of Leeds
Leeds LS2 9JT
Email: edvam@leeds.ac.uk

January 2014

Appendix 5 Responses to ethics committee

The progression over time of profiles of children with Developmental Coordination Disorder (DCD)

Ethics Reference: AREA 12-121

2nd summary response for Leeds University ethics committee (19.01.14)

Please find attached the changes (highlighted in yellow) to the parent information (Appendix 1), child information (Appendix 3) and parent consent (Appendix 2) sheets following advice from Leeds ethics committee and discussion with David Sugden on 9.1.14.

The changes include:

1. A sentence asking parents to give permission for the researcher to approach their child
2. An amended child information sheet with language easier for an 8 year old
3. The support available to children identified with DCD is made more explicit
4. The workshops will be facilitated by experienced professionals

I will also use two information sheets for parents/schools about DCD from the Can Child organization at McMaster University based on their research on DCD, which will be provided for the children identified with movement difficulties in this study. The two flyers will be Advice for P.E. educators and Accommodations at school

These are available from:
http://dcd.canchild.ca/en/EducationalMaterials/school.asp.

DCD project: ethical reference AREA 12-121

Title: The progression over time of profiles of children with Developmental Coordination Disorder (DCD)

1st Summary response for Research ethics committee University of Leeds (15.9.13)

A9, A10 and C7 (i) (ii)

The cohort of children identified by teachers as having, or not having movement difficulties do not already have a diagnosis. This is crucial to the study, as previous research has shown that clinic populations and school populations of children with DCD (i.e. not known to a clinic and therefore probably undiagnosed) contain quite different types of children:

- Clinic children are more likely to have associated characteristics and meet diagnostic criteria for one or more other developmental disorder. It is likely too that they may have more severe symptoms (Kaplan et al. 2001)
- School population children may have better coping strategies or other characteristics that have enabled them to avoid coming to the attention of referral agents before the age of 8-16 years. This is an area that we will be exploring in this study and we hope will give us insight into helping children in the future.

Part of a teacher's role is to evaluate a child's profile of skills and identify any specific needs for support throughout the curriculum. These are then usually discussed with parents during term, or at particular meetings, such as parent's evenings. This is not generally thought to raise anxiety, rather raise awareness for understanding of the nature of the problem and how to support improved learning, which leads to better outcomes for the child. It is appropriate for teachers to highlight potential difficulties, but it should be noted that it would not be until the child has undergone the battery of assessments that the nature of any difficulty will be able to be determined.

Each school has a Special Educational Needs Coordinator (SENCO) who is able to advise and support the teachers if they suspect that any child may have additional special needs. Furthermore, the SENCOs have regular meetings and in-service training with paediatric therapists from the local community team to discuss movement difficulties and children with medical diagnoses, so they already have a reasonable awareness of developmental disorders.

Parents will be given information about the study via the school and can opt out straight away by informing the teacher if they do not want their child to take part. The remaining parents will then be given consent forms for their child to take part in the study and undergo assessment. All parents will have to give consent to have their child assessed. Any child whose parent who decides that they would not like to have their child assessed will be excluded from the study.

Please refer to the decision tree for an explanation of the pathway for the consent process.

C 7(ii) The information sheet covers all categories because it will not be known which category the child will meet until the battery of assessments is complete. However, once the child has been assessed the parents and the child will be informed of the results and consequently which arm of the study they will be in.

A 10 After discussion it was decided to provide each school and clinic with a brief written summary of progress of the project rather than through Facebook.

C 2 Interview information:

The aim of the interviews is to explore the subjective experiences of the children with DCD and DCD plus associated characteristics and those of the adults that support them. The theoretical stance will be phenomenological and will form will be semi-structured interviews, so that issues that arise can be explored in more depth with the used of grand tour questions such as “tell me about what it is like…”. This will be informed by previous qualitative studies in

DCD, the majority of which have covered the parent's perspective of a child with DCD (Iverson et al. 2005; Mandich et al. 2003; Missiuna et al. 2006; Missiuna et al. 2007), some the young adult perspective with DCD (Missiuna et al. 2008; Kirby et al. 2008) and fewer the child's perspective (Dunford et al. 2005). An interview schedule, such as that proposed by Missiuna et al. (2008) comprising the main anticipated issues from previous research on DCD and areas that focus specifically on the research question for this study will cover two of the ICF categories of participation in self care and community, social and civic life:

- Life and progress in school, participation in physical activity, sports, friendships, academic strengths/weaknesses, organization skills, best/worst times, strategies
- Leisure pursuits, type/importance /enjoyment/motivation/frequency

- Self care- differences /problems/strategies
- Use of probes – "can you tell me more about that?" "what helps?" "what do you like/dislike about that?"
-

This schedule will be used for both the experiences of the child with DCD (and DCD plus associated characteristics) and their parents.

The teacher interviews however, will focus on their perspective and include:

- Differences both positive and negative/frustrations/unexpected outcomes
- Effects on child/class
- Strategies
- Information that I wish I had before

C 3 Follow up interviews for parents and teachers may take place over the phone for their convenience but all child interviews will be face to face.

C11 There is sparse longitudinal data on DCD and there will be both quantative and qualitative from this study, which will be valuable to compare with future studies. Should the same participants be invited to take part in a future study the appropriate permission would be sought and new ethical approval and consent would be sought before it could go forward.

C15 The interviews:

a) Those with the parents will be conducted by VM, an experienced paediatric OT with 18 years of experience of talking and listening to parents about sensitive subjects concerning their children. The interviews will take place in a private room, either at school or in the parent's home if preferred, and will take approximately half an hour. The topic of the interviews have been outlined above and will aim to gain the parent's perspective of how the movement and other characteristics effect family life and their child's ability to participate in daily life. We will be particularly interested in strategies that families have found helpful to them and areas of particular difficulty.
b) Those with children will also be conducted by VM. The interviews will take place in school in a private room and will take approximately half an hour as outlined above. The child's perspective is important and may well differ from the parent's. They will be reassured that they can stop at any time, or take a break if any sensitive subjects arise.
c) Those with teachers will be conducted by VM and will differ from that of the child or parent interviews in that they will seek the perspective of the teacher on the effect on the class, any strategies or information that has been helpful or unhelpful.

C 15 A different information sheet will be used for interviews.

C6, C 18 Risk assessment is required for lone working

C 19 Personal records will include clinic records for the clinic cohort and school records for the school cohort and these will be assessed by VM. These will be required to determine the nature of the medical diagnoses in the clinic population and any intervention they may have had, and the school records will be required to determine school progress.

Appendix 3 After discussion the child information sheet was considered appropriate for children of 8-16 years. Pictures or much simpler language may be considered patronizing for children of 8 years old.

Appendix 6 Parent Questionnaire

Parent Questionnaire

About you and your family

1. Name: 2. Postcode:

2. Have you or any close relative been diagnosed with one of the following? Please tick more than one if appropriate:

ADHD attention	DCD/dyspraxia movement	Dyslexia reading	Autistic Spectrum D	Language impairment	Other	None

3. Who lives at home? Please tick and state number of children in each group

Mother	Father	Children under 5	Children aged 5-11	Children aged 12-18	Young people 18+

4. How would you describe your current health? Please tick one box

Healthy	Health problems	Registered disabled

5. Employment for you and your partner: Full time (FT), Part time (PT) please tick one box

Both parents FT	One FT or both PT	One parent FT	One parent PT	Not working

6. Highest level of your education (mother only): please tick one box

High school	High school with GCSE	'A' level	College diploma	H E Degree	Post grad degree

7. Are your children entitled to free school meals? Please circle: Yes/no

8. Family transport: do you have a car(s)? Please tick one box

0	1	2 (or more)

9. How important is sport or physical activities to your family? Rank 1= not very to 4= very important: please circle: 1 2 3 4

10. It is hard to find time sometimes but how much physical activity/sport are you able to do regularly? Please tick one box

Twice weekly	Weekly	Twice monthly	Monthly	Rarely

11. Rank how much the level of your child's coordination interferes with family life: 1=not at all 4= very much: 1 2 3 4

Appendix 7 Interview schedule

Child Interview:

Child's name:

Date of interview:

Information sheet given, voice recorder explained: yes/no

Consent form signed: yes/no

Child Interview Schedule Prompts:

1. Tell me about yourself
2. What do you like doing?
3. What is good about being you?
4. What is school like for you? Friends/classwork/playground
5. What do you enjoy?
6. Is there anything you struggle with at school? Or home?
7. How do you cope?
8. Who/what helps you most?
9. You have already told me that you enjoy/don't enjoy physical activity & P.E, why is this?
10. What do you do after school and at the weekends? Organized? Or free play?
11. What does your mum or dad think of you?
12. If you could wave a magic wand to change something what would it be?

After Lingam et al., 2013.

Appendix 8 Publications and conference presentations arising from the study

McQuillan, V.A. et al. (2015) *Intervention and support in DCD: from research to practice* Journal of Comorbidity*, 5 (32). Pp. 32-109.* DOI: 10.15256/joc.2015.5.52

McQuillan, V.A. (2015) *Stability and change over time in children with movement difficulties*. Hillary Place Papers, 2nd edition, 2. Online Journal

McQuillan, V.A. et al. (2013) *The progression over time of profiles of children with developmental coordination disorder.* (2013) Brazilian Journal of Motor Behaviour, 7. p. 8. ISSN ISSN 1980-5586

Conference presentations (unpublished)

McQuillan, V.A., Swanwick, R.A., Chambers, M.E. & Sugden, D.A. *(2019) What do detailed motor and non-motor profiles of children with DCD tell us about motor progression over time? DCD 13th International Conference 5-8th June 2019, Jyvaskyla, Finland.*

McQuillan, V.A., Swanwick, R.A., Chambers, M.E. & Sugden, D.A. (2018) *How detailed profiles of children with Developmental Coordination Disorder (DCD) influence participation in physical activity (PA). School based evidence.* 7th Biennial Academic and practitioner conference on DCD, Brunel University, 29th -30th June 2018.

McQuillan, V.A., Sugden, D.A., Chambers, M.E., Swanwick, R. (2017) *How can we broaden the horizons for children with developmental coordination disorder? -Evidence from a collaborative study. 'Broadening Horizons: Celebrating Collaborative Practice'* Royal College of Occupational Therapy Children Young People and Families, specialist section conference, Leeds 2017.

McQuillan, V.A., Sugden, D.A., Chambers, M.E., Swanwick, R. (2017) *Progression and participation in children with and without DCD and associated characteristics: A longitudinal study.* DCD 12th International conference, 5-8th July 2017 Perth Australia.

McQuillan, V.A., Sugden, D.A., Chambers, M.E., Swanwick, R. (2017) *DCD and associated characteristics: what facilitates participation in physical activity?* DCD 12th International conference, 5-8th July 2017 Perth, Australia.

McQuillan, V.A., Sugden, D.A. , Chambers, M.E., Swanwick, R. (2016) *Stability and change in children with and without development coordination disorder. Oral presentation: 6th Biennial Conference DCD UK, University of Leeds, 22 & 23rd July 2016.*

McQuillan, V.A. *(2013) An investigation of the influence of associated characteristics on the progression of children with developmental coordination disorder.* In: Symposium on motor impairment, 3.6.2013, University of Leeds.

McQuillan, V.A. *(2012) The progression of profiles of children with developmental coordination disorder over time*. In: Salford Postgraduate Research Conference, May 2012, Salford University.