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European Master in Health and Physical Activity

Influence of Sport Stacking on hand-eye coordination in children aged 7-11

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Abstract

Background: Awareness of impact of movement difficulties on children's lives has increased dramatically over the last 20 years (Sugden & Henderson, 2007). Basically, these children exhibit difficulty in coordinating their movements and learning fine and gross motor skills, so that as results their impaired motor performances often affect their social and psychological well-being. Moreover, poor motor coordination, in its broader meaning, can present very differently and show widely different profiles of performance (Visser, 2003). Therefore, these motor difficulties can refer to a heterogeneous condition in which children frequently present with co-occurring conditions in addition to their motor problems (Green et al., 2008) such as DCD (Developmental Coordination Disorder), ADHD (Attention Deficit Hyperactivity Disorder), SLI (Specific Language Impairment), and so on.

Objectives: Although a lot of approaches to intervention treating coordination disorders and grounded on different theoretical frameworks have been widely discussed, the main aim of this study is to assess the effectiveness of *"sport stacking"*, a quite recent sport adopted by many PE programs (Speed Stacks Inc.), on both children with poor motor coordination and typically developing children. In fact, sport stacking seems to improve, in a fun and challenging way, several rudimentary fine motor skills, such as hand-eye coordination, which is assessed in this study, and others such as bimanual coordination, ambidexterity, reaction time, concentration and quickness. Moreover, the second hypothesis of this study is that any improvement in either hand-eye coordination or general motor coordination positively affects generalized self efficacy toward physical activity and handwriting.

Methods: The experiment involved 20 children of two different primary schools from the Merseyside area of Liverpool, aged between 7 and 11 years, screened before and assessed after the sport stacking training. The main assessment tools employed were the Movement Assessment Battery for Children (MABC-2) to assess the children's motor coordination level (Henderson, Sugden & Barnett, 2007), the Children's Self Perceptions of Adequacy in and Predilection for Physical Activity (CSAPPA) (Hay, 1992) to assess their generalized self efficacy toward physical activity, and the Detailed Assessment of Speed of Handwriting (DASH) (Barnett, Henderson, Scheib & Schulz, 2007) to assess their handwriting velocity.

The sport stacking training consisted of a 4-week program of 3 sessions per week, 45 minutes each. The sections focus was on the learning of the sport stacking sequences in order to apply them in many kinds of physically active plays and relays. Finally, we appraised the gap between the beginning and end of the training.

Results and conclusion: The overall improvements achieved by the children assessed let the author claim that even a short period of proposed training, i.e. sport stacking combined with physically active games, affected not only children's hand-eye coordination and several related fine motor coordination skills, such as handwriting velocity, but also their general motor coordination. Moreover, among the 15 children, who completed the post-test, 5 were classified as having DCD in the pre-test; but only one of them was still classified as being "at risk" for DCD after the post-test. Nevertheless, according to the CSAPPA results, there were no significant results pertaining to children's generalized self-efficacy toward physical activity.

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1 Introduction

Awareness of impact of movement difficulties on children's lives has increased dramatically over the last 20 years (Sugden & Henderson, 2007). Indeed, a large number of school-aged children present with motor-based performance problems, such as everyday skills as tying their shoes, writing their name, or riding a bike, that could have significant negative effects on their ability to participate fully in the daily activities of home, school, and play as well as their social and psychological well-being (Polatajko & Cantin, 2005).

These children are frequently brought to the attention of the family doctor and referred to health care professionals in search of answers and services.

Their coordination deficits may be in gross motor skills, fine motor skills, or both. Some children may have difficulties with discrete finger movements and others with eye-hand coordination. Some children may have poor balance, and others may have reached developmental milestones later than their peers (Dewey & Wilson, 2001).

Studies attempting to describe their coordination deficits have shown that, as a group, the motor performance of these children is consistently slower, less accurate, less precise, and more variable than that of their peers (Smits-Engelsman et al., 2003).

Although these motor coordination deficits are well documented in the literature, and *DSM-IV* calls for "motor coordination. .... substantially below that expected given the person's chronological age" (APA, 1994), specific diagnosis remains a problem facing researchers and clinicians alike (Crawford et al., 2001).

Importantly, a coordination deficit can also be indicative of other general medical conditions such as a sensory impairment, neurologic disorder, or intellectual deficit, so that clinicians need to exclude other different causes. Therefore, a correct diagnosis must rely on a careful history that includes a review of achievement of motor milestones, motor coordination abilities, sensory abilities, and a physical and neurologic examination (Polatajko & Cantin, 2005). However, the presence of "soft" neurologic signs such as associated movements during motor action, abnormal reflexes, mild hypotonia, or dysmetria does suggest the presence of DCD (Developmental Coordination Disorder), a syndrome that comprehends a heterogeneous group of children showing poor motor performance with consequences lying at various level and often combined with co-morbidities such as ADHD (Attention Deficit Hyperactivity Disorder), SLI (Specific Language Impairment) and so on (Wilson, 2005).

Essentially, by using the literature, we find a growing amount of evidence to suggest that the inappropriate motor performances these children experience will not simply disappear with time, especially when the problems are severe and no remediation is provided (Rintala et al., 1998).

Many researchers think that through active participation in play, a child is able to interact and explore his or her environment. Importantly, this leads the increase of "socialization, creativity, language development, problem-solving abilities, and sensorimotor skills" (Cooper, 2000). Moreover, many occupational therapists use play as a therapeutic modality, to increase a child's play skill or to facilitate playful behaviours in a child (O'Brien, 2008).

Consequently, according to the above mentioned statements that assume the play as an important and fundamental tool and that can improve either directly or indirectly a lot of skills throughout the children's development, although a lot of approaches to intervention treating coordination disorders and grounded on different theoretical frameworks have been widely discussed, the first purpose of this thesis is to assess the effects of a specific play/sport training, exactly "sport stacking", on children with poor motor coordination and on typically developing children.

The sport of cup stacking or sport stacking originated as a recreational activity some 20 years ago. It has been even adopted recently by many physical education programs to enhance rudimentary motor skills such as hand-eye coordination and ambidexterity as well as quickness and concentration.

Sport stacking can be, indeed, included within the hand-eye coordination activities; furthermore it requires from who plays several abilities that are often impaired in children that show insufficient motor performances, such as concentration, sensory-motor perception and visuo-motor ability, proprioception, fine motor control (feed-back and feed-forward controls), bimanual coordination, facing fluently a motor sequence, that are all the capabilities we need to arrange and carry out a functional plan as accurately and quickly as possible (Undermann et al., 2004).

The author supports the hypothesis that the sport stacking activity could improve the above mentioned abilities that it requires in the same way as any other sports training. Moreover, hand-eye coordination, the underlying skill required, could be transferred into the various ADL (activities of daily living), into sport/recreational activities and especially on academic requirement such as handwriting. In addition, all this achievements could affect in a positive way the children's psycho-social life, not only by improving hand-eye coordination and transferring it into life, but also just by participating in sport stacking as a teamwork. Finally, the author aims at understanding if after such training their self efficacy toward physical activity will be increased.

Summarizing, this experimental research aims at understanding if a relatively short period of sport stacking training can effectively improve several fine motor skills such us hand-eye coordination and handwriting (in particular handwriting velocity) among primary school children.

2 Literature Review

2.1 Development

A useful manner to explain how a child can show a different motor performance rather than one another is to deal with several underlying characteristics, definitions and concerns about development (Haywood & Getchell, 2009):

- ⇨ it is a continuous process of change in functional capacity, such as the capability to exist, live, move, and work, within the real world. This is a cumulative process. Living organisms are always developing, but the amount of change may be more noticeable, or less noticeable, at various points in the life span;
- ⇨ it is related to (but not dependent on) age. As age advances, development proceeds. However, development can be faster or slower at different times, and rates of development can differ among individuals of the same age. Individuals do not necessarily advance in age and advance in development at the same rate. Further, development does not stop at a particular age, but continues throughout life;
- ⇨ it involves sequential change. One step leads to the next step in an orderly and irreversible fashion. This change results from interactions both within the individual and between the individual and the environment;
- ⇨ the term "motor development" refers to the development of movement abilities. Those who study motor development explore development changes in movements, as well as the factors underlying those changes, such as the interacting constraints (or factors) in the individual, environment, and task that drive these changes;
- ⇨ "motor learning" refers to the relatively permanent gains in motor skill capability associated with practice or experience (Schmidt & Lee, 2005);

- ⇨ we use the term “motor behaviour” when we prefer not to distinguish between motor learning and motor development, or when we want to include both;
- ⇨ “motor control” refers to the nervous system’s control of the muscles to permit skilled and coordinated movements. In other words motor control is the study of the neural, physical, and behavioural aspects of movement (Schmidt & Lee, 2005);
- ⇨ in recent years, researchers in motor development and in motor control have found much in common. Understanding how the nervous system and movement abilities change with age expands our knowledge of motor control, and so we now see much overlap in motor development and control research.

2.2 Motor development theories

Much has been written about the developmental schedule of motor skills in infancy and early childhood, however relatively little is known about how motor skills emerge or the process that drives this change. Moreover, there is no consensus among movement theorists, scientists or clinicians about how movement develops or is controlled (Shumway-Cook & Woollacott, 2001).

Therefore, in this section we briefly deals with the most popular early and modern theories in which motor development and motor control are grounded.

2.2.1 Early motor theories

Early motor theories include the reflex theory (Sherrington, 1947) and the hierarchical theory (Schaltenbrand, 1928). These theories claim that reflexes are the building blocks of complex behaviour and that the nervous system is organized in a hierarchical fashion; importantly, they gave rise to the neuromaturational model of motor development, which many consider to be a classical theory of motor development. This model proposes that motor skills emerge in a predictable sequence driven by the maturation of the central nervous system (CNS) and that instruction for development is “hard-wired” in the brain. Interestingly, according to this model, the environment plays a secondary role in the emergence of motor skills.

In other words, the neuromaturational model is grounded in a basically medical model in conjunction with neuromaturational norms that have traditionally been used as a basis for understanding signs of abnormal motor development; it has guided the selection and interpretation of assessment tools. Furthermore, in opting to use it in a clinical setting, the user is implicitly accepting the assumption that the neuromaturational status of the child best explains his/her behavioural profile (Wilson, 2005).

This model has been criticised by more recent researchers that abandoned early motor theories such as the neuromaturational model (Ulrich, 1997; Shumway-Cook & Woollacott, 2001). The assumption that the sequence of motor development is consistent and predictable, as this model claims, has also been challenged. Researchers have shown that infants acquire skills at different ages (Darrah et al., 2003). They indicated there is large variability in motor scores within individual infants, among infants, and across developmental domains on motor testing. They concluded that typical development is non-linear rather than occurring at a constant rate. In particular, fine motor and gross motor skills appeared to develop independently.

2.2.2 Modern theories

Contemporary motor theories take the relationship of the environment and the individual's experience to the development of motor skills into consideration. This has given rise to the ecological perspective or theory (Gibson, 1966), motor program theory (Bernstein, 1967), dynamical systems theory (Bernstein, 1967; Newell, 1985), and motor control theory (Shumway-Cook & Woollacott, 2001).

Among the mentioned contemporary theories, the emphasis will be placed on the ecological perspective and the dynamical systems approach.

Ecological perspective

A new perspective on development appeared during the 1980s and has become increasingly dominant as the theoretical perspective used by motor development researchers today. This approach has broadly termed the ecological perspective because it stresses the interrelationships between the individual, the environment, and the task. This ecological perspective takes into account many constraints or systems that exist both within the body (e.g. cardiovascular, muscular) and outside the body (e.g. ecosystem related, social, and cultural) when observing the development of motor skills across the life span. This perspective is really important to describe, explain, and predict motor development (Haywood & Getchell 2009).

According to the ecological perspective, we must consider the interaction of all constraints. For example, in order to understand the emergence of a particular motor skill, such as kicking a ball, we should consider at the same time: body type, motivation, temperature, and ball size (Roberton, 1989). Although one constraint or system may be more important or may cast a larger influence at any given time, all systems play a role in the resultant movement. Therefore, at any given moment, a given movement is related not only to the body or the environment but also to the complex interplay of many internal and external constraints (Haywood & Getchell, 2009).

Dynamical systems approach

One branch of the ecological systems perspective is called the dynamical systems approach, as an alternative to existing motor control and coordination theories.

The dynamical systems theory of motor development emerged from a "systems theory" approach (Bernstein, 1967), developed in physics and biology, which sought to explain the interaction of multiple subsystems. Fundamentally, these multiple, cooperative systems make up the developing child and their interaction with the task and the constraints of the environment (Wilson, 2005).

Bernstein's (1967) research marked the shift of motor researchers from a maturational model to a dynamical systems approach. Newell (1985) and Ulrich (1997) have further developed the dynamical systems approach. This suggests that movement results from the interaction of both physical and neural components. Accordingly, organisation of movement appears to be the critical aspect that drives motor development (Case-Smith & Bigsby, 2000).

Unlike the maturational and information processing perspectives, the dynamical systems approach suggests that coordinated behaviour is “softly assembled” rather than hardwired, meaning that the interacting constraints within our body act together as a functional unit to enable us, for instance, to walk when we need to (Haywood & Getchell, 2009). By not having a hardwired plan, we have greater flexibility in walking, which allows us to adapt our walk to many different situations. This process is called spontaneous self-organization of body systems (Haywood & Getchell, 2009). Therefore, movement emerges from the interaction between constraints (individual, environmental, task) and the resultant behaviour emerges or self-organizes from these interrelationships. If we change any one of them, the emergent movement may change (Clark, 1995). This is the concept of constraints within the dynamical systems approach.

Another important motor development concept produced by the dynamical systems approach is the notion of rate limiters or controllers: the body’s systems do not develop at the same rate; rather, some might mature quickly, and others more slowly, and each system should be considered a constraint (Haywood & Getchell, 2009). An individual might begin to perform a new skill, such as walking, only when the slowest of the necessary systems for that skill reaches a certain point. In other words, the system acts as a constraint that discourages the motor skill until the system reaches a specific, critical level (Haywood & Getchell, 2009).

The Newell's constraints model (1985), dealt with below, can be of help to better understand the meaning of the concept of "constraint" within the dynamical systems approach. Moreover, this model is a useful tool in explaining the motor development across the life span.

Newell's model

Karl Newell (1985) suggested that movements arise from the interactions of the organism (or the individual), the environment in which the movement occurs, and the task to be undertaken. If any of these three factors change, the resultant movement changes. In short, to understand movement, we must consider the relationships between the characteristics of the individual mover, his surroundings, and the purpose or reasons for his moving. From the interaction of all these characteristics, specific movements emerge.

If we think about the different ways in which individuals can walk, for example, a toddler taking his first steps, a child walking in deep sand, an adult moving across an icy patch, or an older adult trying to catch a bus. In each example, the individual must modify his or her walking pattern in some way. These examples illustrate that changing one of the factors often results in a change in the interaction with one or both of the other factors, and a different way of walking arises from the interaction. For example, whether an individual is barefoot or wearing rubber-soled shoes might not make a difference in his walking across a dry tile floor, but his walk might change notably if the floor were wet and slippery. The interaction of individual, task, and environment changes the movement, and, over time, patterns of interactions lead to changes in motor development.

Newell's model is helpful in studying motor development because it reflects the dynamic, constantly changing interactions in motor development. It allows us to look at the individual, at the many different body systems that constantly undergo age-related changes. At the same time, the model emphasizes the influence of where the individual moves (environment) and what the individual does (task) on individual movements. Changes in the individual lead to changes in his or her interaction with the environment and task and subsequently change the way the individual moves. Moreover, the individual, environment, and task influence, and are influenced by each other.

These three factors: individual, environment and task, are called by Newell "*constraints*". A constraint limits or discourages, in this case, movement, but at the same time it permits or encourages other movements. It's important not to consider constraints as negative or bad. Constraints simply provide channels from which movements most easily emerge. Newell (1985) described three types of constraints: organismic constraints (including neurological integrity, biomechanical factors, muscle strength), environmental constraints (including gravity, lighting), and task constraints (including the goal of the task, rules, implements available).

- ⇨ Individual constraints are a person's unique physical and mental characteristics. For example, height, limb length, strength, and motivation can all influence the way an individual moves. Individual constraints are either structural or functional.
- ⇨ Structural constraints relate to the individual's body structure. They change with growth and aging; however, they tend to change slowly over time. Examples include height, weight, muscle mass, and leg length.
- ⇨ Functional constraints relate not to structure but to behavioural function. Examples include motivation, fear, experiences, and attentional focus, and such constraints can change over a much shorter period of time.

Environmental constraints exist outside the body as a property of the world around us. They are global, not task specific, and can be physical or socio-cultural. Physical environmental constraints are characteristics of the environment, such as temperature, amount of light, humidity, gravity, and the surfaces of floors and walls. Socio-cultural environment can also be a strong force in encouraging or discouraging behaviours, including movement behaviours.

Task constraints are also external to the body. They include the goals of a movement or activity, the rule structure surrounding that movement or activity, and choices of equipment.

It can be finally asserted that Newell's model guides us in identifying the developmental factors affecting movements, helps us create developmentally appropriate tasks and environments, and helps us understand individual movers as different from group norms or averages.

The above mentioned theories all deal with motor control and the way it develops in order to give researchers and clinicians a rationale to treat movement coordination deficits. The movement coordination deficit emphasized in this dissertation, and extensively discussed within the next section, is called Developmental Coordination Disorder (DCD).

2.3 Developmental Coordination Disorder

During typical development, experience and maturation interact to influence the development of musculoskeletal and neuromotor system, which enable children's motor skills to improve with increasing age. There are some children who exhibit difficulty co-ordinating their movement and for whom learning motor skills is very hard (Savelsbergh et al., 2003).

Interestingly, over the last 20 years, awareness of impact of movement difficulties on children's lives has increased dramatically (Sugden & Henderson, 2007). Their coordination deficits may be in gross motor skills, fine motor skills, or both. Some children may have difficulties with discrete finger movements and others with hand-eye coordination. Some children may have poor balance, and others may have reached developmental milestones later than their peers (Dewey & Wilson, 2001). For some, such children are seen to have a delay in motor development; however, their developmental pathway is different compared to their typically developing peers (Savelsbergh et al., 2003).

Studies attempting to describe their coordination deficits have shown that, as a group, the motor performance of these children is consistently slower, less accurate, less precise, and more variable than that of their peers (Smits-Engelsman et al., 2003).

Importantly, a coordination deficit can also be indicative of other general medical conditions such as a sensory impairment, neurologic disorder, or intellectual deficit, so that clinicians need to exclude other different causes. Therefore, a correct diagnosis must rely on a careful history that includes a review of achievement of motor milestones, motor coordination abilities, sensory abilities, and a physical and neurologic examination (Polatajko & Cantin, 2005). Thus, whether children's motor-based performance problems, such as everyday skills (e.g. tying their shoes, writing their name, or riding a bike), have even a "significant negative impact" on quality of live, they could suffer from a neurodevelopmental disorder most commonly known as developmental coordination disorder (DCD) (Polatajko & Cantin, 2005).

The Diagnostic and Statistical Manual (DSM) describes DCD as a motor skill disorder characterized by a marked impairment in the development of motor coordination abilities that significantly interferes with performance of daily activities and/or academic achievement. The difficulties observed are not consistent with the child's intellectual abilities and are not caused by a pervasive developmental disorder or general medical conditions that could explain the coordination deficits (American Psychiatric Association, 1994).

Although the American Psychiatric Association (APA, 2000) reports on its *DSM*-4th edition that DCD affects 5-6% of children, recent reviews show that, since the estimated prevalence depends on specific criteria, DCD can occur in up to 15% of children, showing that it is a significant disorder (Wilson, 2005). The ratio of males to females who are identified with DCD has changed over the past years from 1:9 (1 girl to every 9 boys) up to, most recently in 2001, 1:3. However, surveys of motor skills in the wider population of children, as distinct from the clinical referrals, reveal that gender distribution is more equal (Savelsbergh et al., 2003). Approximately 25% of children with DCD will be referred before starting school at (from 3 to 5 years of age). The remaining 75% will be referred during the first few years in primary school (from 6 to 8 years of age) (Gibbs et al., 2007).

This syndrome comprehends a heterogeneous group of children showing poor motor performance often combined with attention and learning comorbidities, the most common are ADHD (Attention Deficit Hyperactivity Disorder) and SLI (Specific Language Impairment) (Wilson, 2005). Moreover, a number of co-ordination subgroups have emerged from cluster analysis of children's performances on a range of sensory, perceptual and motor tasks. For example, Hoare (1994) described five subgroups within a pool of 80 children identified as having motor difficulties. Scores were obtained from a number of tests that measure kinaesthetic acuity, visual perception, visual-motor integration, manual dexterity, static and dynamic balance, and gross motor co-ordination (Hoare, 1994; Macnab et al., 2001).

2.3.1 Aetiology

Wall et al. (1990) stated that motor performance is the end product of numerous interacting psychological, sociological, physiological and hence neurological systems; so that it is not surprising that the aetiology of DCD would be quite diverse and complicated.

Some authors have suggested that factors relating to pregnancy, such as, smoking or viral infection during pregnancy, anoxia, may contribute to the neurological soft signs relating to DCD (Lefebvre, 1996). Nevertheless, the most important issue to be considered for aetiology and linked to pregnancy is the big incidence for DCD of children either born prematurely or children of low birth weight (Davis at al., 2007).

Although the pathophysiology is basically unknown, children with DCD appear to have underlying difficulties in motor planning (planning movements such as sitting down on a chair or figuring out how to jump) and the integration of information from sensory and motor systems (e.g., relying heavily on visual rather than on proprioceptive information to climb stairs or fasten buttons) (Wilson, 2005). This, in turn, impairs quality of movement, especially in situations where the child has to react to a changing environment (Wilson, 2005).

Therefore, according to sensory integration theory, the primary basis for the poor motor performance of children with DCD lies in the central processing and integrating of information related to planning, selecting, organization, timing and sequencing of movement and behaviour (O’Brian et al., 2008).

The result is that these children show inefficient, poorly timed movements and seem to lack natural rhythm. Thus, some may be especially vulnerable to failure in tasks that require consistent, repetitive actions (serial, closed tasks) whereas some other may have added difficulty with tasks involving complex timing of movement to information from the external environment (open tasks) (Williams, 2002).

Another issue to take in account is that overall, children with DCD tend to have longer Reaction Time (RT) (Williams, 2002); that is an indication of the speed with which an individual can process input and prepare and initiate a response. Moreover testing RT can provide important information about the nature of the CNS involvement in the fine-motor dysfunction associated with DCD (O'Brien, 2004).

From a sociological perspective, family, school, and other environmental factors have also been suggested as possible causes of DCD (Lefebvre, 1996).

Causal modelling, a way to approach DCD aetiology

A quite recent approach, which can help us to interpret DCD aetiology, is the Causal Modelling (Morton 2004; Morton & Frith, 1995), a cognitive scientific model that seeks to combine environmental, biological, cognitive and behavioural levels of description (Howard-Jones, 2006). This approach reflects recent efforts within cognitive neuroscience to model the mind-brain continuum; accordingly, cognition is portrayed as sandwiched between quantifiable performance and scientifically observable biological processes, with environmental factors influencing outcomes at each stage. Therefore, this model emphasizes the mediating role of mind in the relationship between brain and behaviour and provides means of exploring causation in a way that includes mental and biological mechanisms. In other words, Morton and Frith have aimed to associate brain activity (e.g. as observed using neuroimaging) to behavioural outcomes (such as responses from cognitive tasks) via theoretical concepts of cognition (representing the mind).

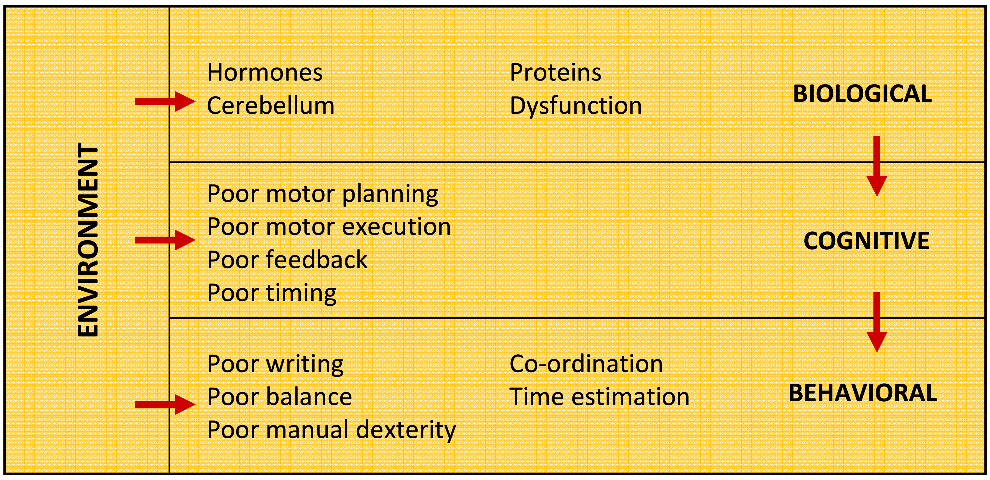

Figure 1. Causal modelling: a way to think about DCD. Three levels of description can be noticed: biological, cognitive, behavioural (Morton, 2004; Morton & Frith, 1995)

Thus, since the causal model is the representation of a causal theory within a particular framework, within a DCD perspective, as shown in figure 1, the causal chain starts with the biological origins (e.g. hormones and dysfunctions), and arrives to the last step, that is the behaviour shown by the children (e.g. poor handwriting, poor manual dexterity, poor balance), passing through a cognitive causal step (e.g. poor motor planning, poor feedback, poor timing) resulting always from both environmental external factors (e.g. teaching, cultural institutions, social factors) and individual internal factors (e.g. memory and emotion). In this manner, explanation of DCD is a function of the interaction between factors at the cognitive and biological levels and from the environment (Krol et al., 2006).

Moreover, such an approach not only gives us a good point of view to interpret the reasons why DCD can occur, but also, as we can see later, it will be really useful for the explanation of the kind of intervention we have proposed in this study.

2.3.2 Characteristics of Developmental Coordination Disorder

Although DCD encompasses a wide range of characteristics, its essential feature is that children have motor learning difficulties and are unable to perform the required actions of daily living in a culturally acceptable way (Savelsbergh et al., 2003; Mandich et al., 2001).

A child with DCD may experience difficulty with self-care tasks, such as dressing or managing cutlery; with academic task, including handwriting, coping, drawing, and organising their workspace (see Figure 2; Goyen, 2005).

The movement problems of these children include a variety of difficulties such as poor postural control and continual misjudgement of distance and time (e.g. bumping into objects and people, tripping over, failing to catch balls), inability to coordinate complex movements necessary to participate in age-appropriate sports and playground activities (e.g. running, kicking, catching, and throwing) (Polatajko & Cantin, 2006). Learning new skills in physical education is a continuous challenge and these children may try to avoid these classes with complaints of illness or problem behaviour (Missiuna et al. 2004).

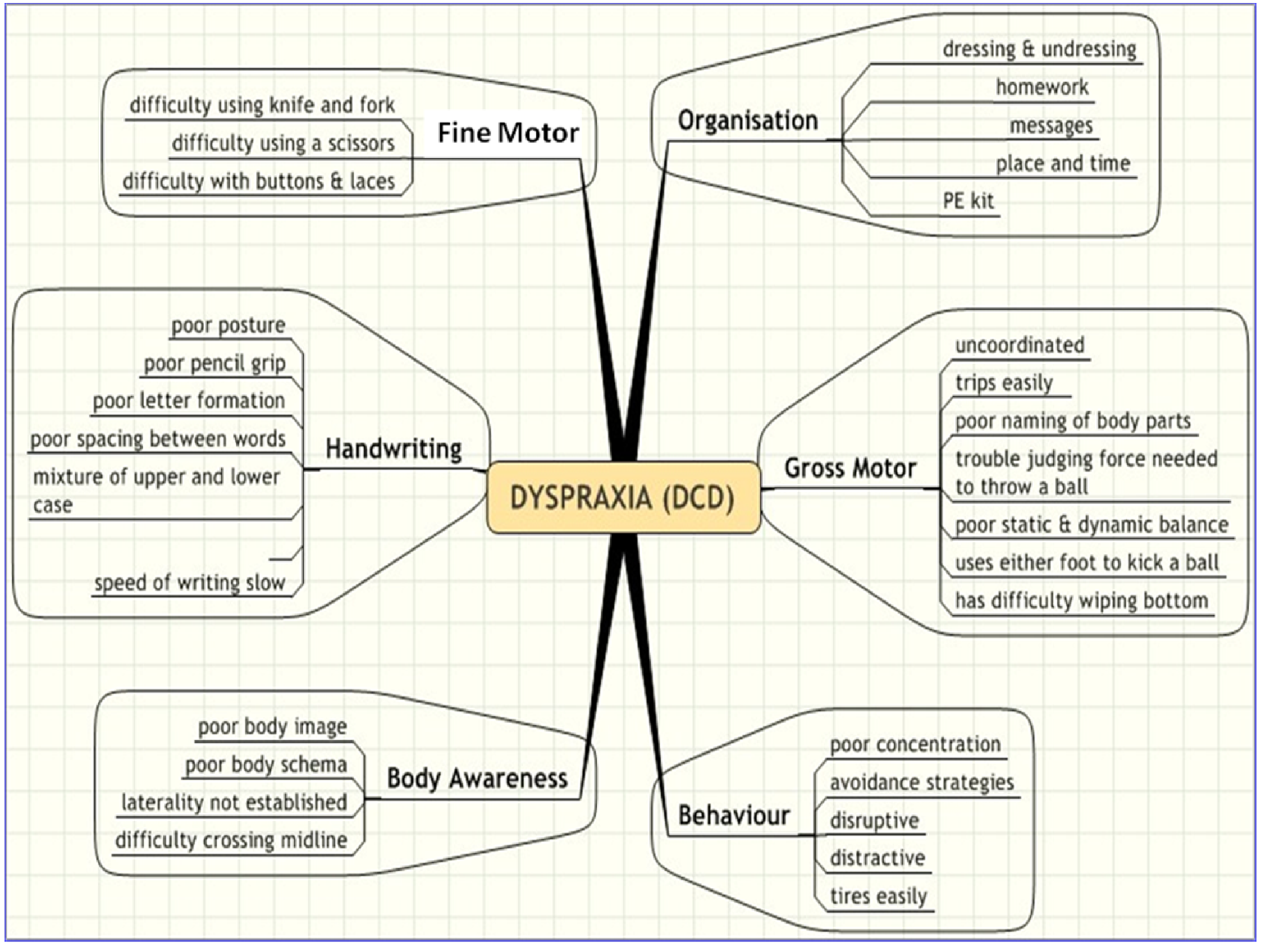

Figure 2: Grossmotor, finemotor and behavioural characteristics in children with Developmental Coordination Disorder

Importantly, motor skills tend to be imprecise or clumsy rather than globally delayed (Spagna et al, 2000). Furthermore, longitudinal studies have highlighted other associated problems, such as behaviour and social and emotional adjustment, which may have greater impact in the longer term (Green et al., 2008; Wilson, 2005).

2.3.2.1 Motor control

According to the main aim of this dissertation to improve several motor coordination skills, in this section we address several issues that could be insufficient among children with poor motor control and even worse among DCD children, such as postural control, hand-eye coordination, hand writing and bimanual coordination.

Postural control

Skilled movement performance, regardless of its end goal, is believed to be a product of two interrelated phases of action: a positioning, postural or preparatory phase, and an executory or manipulative one (Sharon et al., 2001). To balance effectively, the individual must process visual information about the body and external environment, proprioceptive information about limb and body position, and then initiate an appropriate corrective response. The integration or mapping of these two sources of sensory information is also a critical ingredient in balance control (Sharon et al., 2001).

“Balance” is defined as the ability to maintain a weight-bearing posture, or to move through a sequence of postures, without falling, and constitutes an integral and inevitable component of most movement activities; “static balance” is the ability of the body to maintain a desired posture in a stationary position, while “dynamic balance” implies changes in posture (Tsai et al., 2008).

From a developmental point of view, among typically developing children, automatic postural control improves up to the age of about 10 years, with qualitative changes at the level of integrated processing of sensory input around the age of 6 years, and improvement of dealing with conflicting sensory input up to the age of 8 years (Geuze, 2005). Moreover, the degree of postural control and balance acts as a constraint on the development of specific motor skills.

In term of postural control, there is a lot of evidence about the establishment of postural synergies in response to unexpected balance perturbations such as tripping and slipping. In the ages from around 7 to 10, postural synergies, in the matter of speed and consistency of muscle response, become refined, although children as young as 15 months show similar synergies. These postural synergies relate to the pattern of activation of the muscles in the legs and trunk (Savelsbergh et al., 2003).

Researchers (Geuze, 2005; Savelsbergh et al., 2003) claims that poor balance and postural control (moderate hypotonia or hypertonia, poor distal control, static and dynamic balance) is one of the common features of children with DCD and the underlying issue is within the gross motor skill. Indeed, extensive testing of these children indicates that many of them score poorly on measures of static and dynamic balance and these difficulties are displayed in poorly coordinated running, skipping, jumping and hopping (Geuze, 2005).

The main characteristics of poor control in DCD are an inconsistent timing of muscle activation sequences, co-contraction, a lack of automatization, and slowness of response (Geuze, 2005) and the strategies for regulating muscle activity are much less uniform and consistent than in children without DCD (Tsai C.L. et al. 2008). DCD is, hence, associated with larger postural sway and with failing more difficult balance tasks (Geuze, 2005).

Moreover, Geuze (2005) claims that under normal conditions, static balance control is not a problem for these children, only in novel or difficult situations such children are at risk for losing balance. Importantly, for the majority of them, this problem seems not to be due to greater dependence on vision. Converging evidence indicates that cerebellar dysfunction contributes to the motor problems of children with DCD.

Other researchers (Johnston et al., 2002) support the hypothesis that altered postural muscle activity can contribute to poor proximal stability and consequently to poor upper limb coordination of children with DCD. Therefore, it is possible that this poor control is a pervasive underlying constraint on the performance of other gross motor skills in which central/core stability is important to the limb manipulations (e.g. over arm throwing, kicking a ball) (Savelsbergh et al., 2003).

Hand-eye coordination

Hand-eye coordination is a fundamental fine motor skill. It can be defined as the ability of the vision system to coordinate the information received through the eyes to control, guide, and direct the hands in the accomplishment of a given task, such as handwriting or catching a ball. It uses the eyes to direct attention and the hands to execute a task (Laberg, 2006).

We start to develop it very early in life. Between four and 14 months of age, infants explore their world and develop hand-eye coordination, in conjunction with fine motor skills. Fine motor skills are involved in the control of small muscle movements, such as when an infant starts to use fingers with a purpose and in coordination with the eyes. Infants are eager to move their eyes, their mouths, and their bodies toward the people and objects that comfort and interest them. They practice skills that let them move closer to desired objects and also move desired objects closer to themselves. By six months of age, many infants begin reaching for objects quickly, without jerkiness, and may be able to feed themselves a cracker or similar food. Infants of this age try to get objects within their reach and objects out of their reach. Many infants are also able to look from hand to object, to hold one object while looking for a second object, and to follow the movements of their hands with their eyes. At this age, most infants begin to poke at objects with their index fingers.

Table 1. Hand-eye coordination: development milestone (Laberg, 2006).

1) Birth to three years

Between birth and three years of age, infants can accomplish the following skills:

- start to develop vision that allows them to follow slowly moving objects with their eyes
- begin to develop basic hand-eye skills, such as reaching, grasping objects, feeding, dressing
- begin to recognize concepts of place and direction, such as up, down, in
- develop the ability to manipulate objects with fine motor skills

2) Three to five years

Between three and five years of age, little children develop or continue to develop the following skills:

- continue to develop hand-eye coordination skills and a preference for left or right handedness
- continue to understand and use concepts of place and direction, such as up, down, under, beside
- develop the ability to climb, balance, run, gallop, jump, push and pull, and take stairs one at a time
- develop eye/hand/body coordination, eye teaming, and depth perception

3) Five to seven years

Children between five and seven years old develop or continue to develop the following skills:

- improve fine motor skills, such as handling writing tools, using scissors
- continue to develop climbing, balancing, running, galloping, and jumping abilities
- continue to improve hand-eye coordination and handedness preference
- learn to focus vision on school work for hours every day

After six months, infants are usually able to manipulate a cup and hold it by the handle. Many infants at this age also begin to reach for objects with one arm instead of both. At about eight months of age, as dexterity improves, many infants can use a pincher movement to grasp small objects, and they can also clap and wave their hands. They also begin to transfer objects from hand to hand, and bang objects together (Laberg, 2006). (For detail about hand-eye coordination development milestones see Table 1).

Hand-eye coordination problems are usually first noted as a lack of skill in drawing or writing (Rosenblum & Livneh-Zirinski, 2008). Drawing shows poor orientation on the page and the child is unable to stay "within the lines" when using a colouring book. Often the child continues to depend on his or her hand for inspection and exploration of toys or other objects. Poor hand-eye coordination can have a wide variety of causes, but the main two conditions responsible for inadequate hand-eye coordination are vision problems and movement disorders (Laberge, 2006).

Since vision is closely linked to hand-eye coordination it will briefly describe their linkages:

- ⇨ vision is the process of understanding what is seen by the eyes;
- ⇨ it involves more than simple visual acuity (ability to distinguish fine details). Indeed, it also involves fixation and eye movement abilities, accommodation (focusing), convergence (eye aiming), binocularity (eye teaming), and the control of hand-eye coordination;

⇨ most hand movements require visual input to be carried out effectively. For example, when children are learning to draw, they follow the position of the hand holding the pencil visually as they make lines on the paper.

Importantly the delayed processing that children with DCD experience when responding to visual stimuli may explain some of the visual-processing deficits observed in children with motor coordination disorders. If those children take longer to process visual stimuli when organizing a response, then their subsequent movement may be delayed and its subsequent reaction time and timing may be inappropriate (O'Brien et al., 2008).

Handwriting

Handwriting proficiency is an essential activity required for success and participation in school, necessary for 30 to 60% of the school day (Rosenblum et al., 2003), and is a key ingredient in children's self-esteem as well as the most immediate form of graphic communication (Feder & Majnemer, 2007).

Children who are experiencing difficulty learning to print manuscript or cursive letters or who have trouble with the legibility, spacing and organization of letters are usually recognized by teachers in the early grades and are provided with extra instruction, or referred to a Learning Resource Teacher (Rosenblum & Livneh-Zirinski, 2008).

Furthermore, handwriting is often like the "tip of the iceberg" that reveals an underlying motor disorder (Missiuna et al., 2008); indeed, as shown in a study of Missiuna and colleagues (2005), the majority of children who were referred to occupational therapy for handwriting problems met the diagnostic criteria for DCD (Missiuna et al, 2005).

Difficulties in this skill have been even formally recognized in DCD criteria A and B of the DSM-IV (Barnett, 2006) and, as shown by Smith-Engelsamn and colleagues (2001), handwriting is the most frequently mentioned problems in children with DCD (Smits-Engelsman et al., 2001).

Printing/handwriting, among these children, may be illegible, inconsistent in sizing, messy and very effortful. Frequent erasures of work, inaccurate spacing of words and unusual letter formation are evident. Pencil/crayon grasps may be awkward and written work not well aligned. Pencils may be dropped frequently and pencil leads broken or paper torn because they use excessive pressure on the page (Case-Smith & Weintraub, 2002).

Thus, according to O'Hare and Khalid (2002), we can assert that the need of identifying handwriting difficulties as early as possible, both as a preventive and as a corrective aid, is especially pressing among children with DCD because of possible relationships between coordination problems, handwriting deficits, dyspraxia and dyslexia, which may signify that they are at risk for literacy acquisition problems (O'Hare & Khalid, 2002).

Bimanual coordination

One aspect of fine motor movement that is particularly affected by DCD is bimanual coordination. Bimanual coordination is the orchestrated use of the two hands (Bobish, 2003). It is needed with eating skills such as holding a bowl and using a spoon, or holding meat with a fork while cutting with a knife. It is utilized in dressing skills such as pulling pants up, or buttoning buttons. It is used in grooming skills such as squeezing toothpaste onto a toothbrush or washing your face. In school, bimanual coordination is used to hold and turn a piece of paper while cutting with scissors, hold a piece of paper and write, or type on a computer.

It requires the proper functioning of sensory processing, sensorimotor integration, and motor programming; all three of these processes thought to be inadequate in children with DCD (Bobish, 2003). Indeed, Williams et al. (1998) noted longer reaction times (RT) in DCD children when they initiated a bimanual response compared to unimanual response, and proposed that children with DCD treat each limb separately rather than as a coordinated whole.

Although, the potential locus of dysfunction at the neural level is still unclear (Volman & Geuze, 1998), data from Huh et al. (1998) suggest that the bilateral motor coordination deficits often observed in children with DCD may, in part, be a result of a less advanced motor control system and lack of capacity to organize and employ appropriate motor control strategies.

An interesting observation reported by Volman and Geuze (1998), about theirs bimanual coordination study, is that they identified children with DCD who had very poor bimanual coordination patterns but stable visuo-manual coordination actions, and a second group that had the opposite features. Even a third group of children with poor bimanual and visuo-manual coordination patterns was identified. This suggests that the motor control difficulties of children labelled as having DVD are quite diverse.

2.3.2.2 Physical fitness, physical activity and psychosocial implications

Children with DCD are less physically active (Schott, et al., 2007; Bouffard et al., 1996) and have significantly different patterns of social and physical play than their well-coordinated peers (Poulsen & Ziviani, 2004).

They may not participate in PA because they may not perceive themselves to be sufficiently adequate to meet minimum performance expectations (Cairney et al., 2005). Cairney and colleagues (2005) suggest that children with DCD not only perceive themselves to be less competent in basic physical skills (Skinner & Peik, 2001), but also less adequate in their overall physical abilities, are more likely to select sedentary over active pursuits, and are less likely to enjoy physical education classes; in other words they have a low generalized self-efficacy toward physical activity. Moreover, their predilection for sedentary pursuits and an avoidance of structured PA opportunities is likely a coping strategy to deal with the risk of failure and humiliation (Fitzpatrick & Watkinson, 2003).

Salversbergh and colleagues (2003) indicated that a decrease in the time spent with PA not only leads to a lack of practice time for the development of movement skills, resulting in fewer "physical resources" in coping the coordination difficulties, but even results in decreased physical fitness (Savelsbergh et al. 2003; Bouffard et al., 1996). In fact, according to Schott and colleagues, children with DCD performed worse in aerobic and anaerobic endurance as well as in strength measures when controlled for age, gender, and BMI (Schott et al., 2007). Importantly, both low physical fitness and low PA are now accepted as independent risk factors for several chronic diseases (Strong et al., 2005). They are associated with a higher mortality rate, decreased mental health, diabetes, hypertension, and a lower quality of life (U.S. Department of Health and Human Services, 1996).

Interestingly, the avoidance of PA can restrict the ability to perform optimally; placing children with DCD at much greater risk for becoming overweight or obese and obesity will exacerbate the limitations already experienced as part of the disability, consequently hindering opportunities for maximal integration into society (Cairney et al., 2005). Therefore, less physical activity involvement, lower than optimal fitness capacity and poorer coordination abilities combine to create a downward spiral of negative effect resulting in even poorer skills (Savelsbergh et al., 2003).

We can observe the same spiral effect at a psychological level: low physical fitness in children with DCD leads to above mentioned low generalized self-efficacy toward physical activity and fitness compared to their peers, and as a result they are less likely to participate in social and physical activities (Cairney et al., 2005; Dewey et al., 2002; Hay et al., 2004; Skinner & Pick, 2001).

Furthermore, physical activity engagement patterns are multidimensional and tend to track over time with youths at the extremes of PA (i.e. those with the highest and lowest levels of PA) tending to maintain their PA habits as they grow older (Janz et al., 2000; Sherman, 2000).

2.4 Interventions

The DCD intervention approach literature can be categorized into studies that focus on impairment of body function and structure (ie, deficit-oriented perspectives) and studies that focus on activity or participation (ie, task-oriented perspectives) (Polatajko & Cantin, 2006). The former approaches, deficit-oriented, suppose that for children with DCD the motor difficulties they experience are the result of a faulty underlying sensory-motor, or sensory integration systems, and intervention aims to restore function through targeting the impaired body function. Differently, in a task-oriented approach the assumption is that learning will lead to relatively permanent changes in motor performance; so that intervention is focused on task performance and the interaction between the person, task, and environment being paramount (Shumway-Cook & Woollacot, 2001).

The major approaches included in the two above mentioned categories, and summarized in table 2, are treated as following.

Table 2. Summary of major approaches and related articles (Polatajko & Cantin, 2006).

Approaches	References
Sensory Integration (SI)	Allen (1995); Davidson (2000)
Sensory Motor (SM)	Leemrijse (2000); Pless (2000)
Process Oriented (PO)	Sims (1996); Sims (1996)
Task Specific (TS)	Jongmans (2003); Schoemakes (2003)
Parent-teacher intervention CO-OP (PTIP)	Martini (1998); Miller (2001)
General literature review (Lit)	Pless (2000)

Deficit oriented approaches

Sensory Integration Therapy (SIT) is a popular method of intervention that is commonly used by occupational therapists and that is based on the sensory input and integration part of an information-processing model. SIT originated in the work of Ayres (1979) who noted that many motor difficulties were not a problem of motor execution but were more likely to be an inability to process sensory information. She viewed difficulties as residing in motor planning and, thus, concentrated on the information that was coming into the system and being integrated rather than on the motor output. Intervention helps children through providing proprioceptive, tactile/kinaesthetic, and vestibular stimulation aimed at remediating the proposed underlying sensory deficit rather than at improving the performance of a specific behaviour or skill.

Early empirical evidence for SIT was promising but since 1990, a collection of individual studies and meta-analyses have called into question the effectiveness of this approach (Polatajko & Cantin, 2006; Pless & Carlsson, 2000).

Recently, Wilson (2005) conducted a review of approaches to assessment and treatment of children with DCD and concluded that the SIT approach had little empirical support and does not follow current thinking on motor control or the learning of movement skills.

A number of other programmes are available that target the specific areas of the brain that are believed to be responsible for motor and other activities.

The logic of these programmes is similar to the SIT programmes in that the specific behaviour is not addressed but remediation is aimed at training specific structural areas of the brain, such as the cerebellum, that are thought to underlie the various functions. Empirical support for these programmes is at best equivocal, yet the methods are still very popular in occupational therapy. Explanations as to why the empirical support is not strong range from the difficulty in not being able to specify exactly what the sensory component of a specific skill might be through to a lack of explanation of the motor components underlying a skill.

Task oriented approaches

Since the early 1990s, a group of approaches has been developed, all differing slightly, yet alike in their eclecticism and in some of the underlying principles. These interventions all utilize variants of cognitive models but apply them within a framework of functional skills. In addition, dynamic systems models can be seen where outcomes are a function of the interaction between the resources the child brings to the situation, the environmental context, and the manner in which the task is presented (Sugden & Henderson, FORTHCOMING). An early work of Henderson and Sugden (Henderson & Sugden, 1992) with their cognitive motor approach emphasized the planning and execution of movement and the use of cognitive skills. Their work was much influenced by the motor performance and learning literature with an emphasis on types of practice and analysis of tasks, and has proved to be effective in school and home situations (Sugden

& Chambers, 2003). However, there was no control group engaged in other types of intervention so conclusions are tentative.

The cognitive motor approach has recently been updated and renamed ecological intervention (EI) (Sugden & Henderson, FORTHCOMING) incorporating more recent theoretical and empirical evidence from the motor development and learning field. EI incorporates all of the principles and practices from the cognitive motor approach but extends it in two ways. First, EI sets intervention in a more family, community, and ecological setting with lifelong participation being a goal. Second, EI places greater emphasis on the actual control of movement using ideas from both information processing and dynamic systems.

Another recent approach incorporating cognitive strategies and functional tasks is the Cognitive Orientation to Daily Occupational Performance programme (CO-OP) from Canada and has delivered some promising results (Polatajko & Mandich, 2004). Cognition forms the basis of CO-OP, which targets skill acquisition, cognitive strategy use, generalization, and transfer of learning. This intervention focuses on the use of cognitive strategies to facilitate task acquisition. The child is actively engaged in choosing the goals and being guided through the learning process using an executive problem-solving strategy. The approach focuses on the learning of motor skills with attention given to specific aspects of the task performance that are causing the child difficulty. This intervention does not attempt to address underlying foundation skills such as balance or sensory integration. Mandich and Polatajko (Mandich & Polatajko, 2005) conclude that this approach meets the demands of parents in that it helps children to succeed, meets the demands of the therapists in that it is goal-oriented and client-centred and, because it is cost-effective and evidence-based, meets the demands of administrators.

A number of other intervention schemes use functional skill approaches or invoke cognitive strategies. Task specific intervention schemes have been promoted in Australia by Larkin and Parker (2002) and, in the Netherlands, neuromotor task training is promoted, with its foundations built upon motor learning principles (Schoemaker & Smits-Englesman, 2005).

Although a lot of approaches to intervention treating coordination disorders and grounded on different theoretical frameworks have been widely discussed, sport stacking is proposed in this dissertation as an effective intervention to improve, in a funny and challenging way, several rudimentary fine motor skills, especially hand-eye coordination and RT (Udermann et al., 2004). The basic development and mastery of both skills, above mentioned, allows one to engage productively in additional motor skill development, designed to increase overall motor skill proficiency and facilitate participation in a variety of lifetime sporting and fitness-related activities. Moreover, basic motor skills must be developed for everyone to become proficient in movement, and many activities require the fundamental development of hand-eye coordination and RT.

Therefore, according to the above mentioned approaches to intervention and related theories, it can be hypothesized that sport stacking can be referred to as a process-oriented training concerned with the specific motor control functions, that is principally hand-eye coordination, and with the faulty sensory systems that sub serve performance. Furthermore, it requires from the players several abilities that are often impaired in children with DCD, such as concentration, sensory-motor perception and visuo-motor ability, proprioception, fine motor control (feed-back and feed-forward controls), bimanual coordination, facing fluently a motor sequence, that are all the capabilities we need in order to arrange and carry out a functional plan as accurately and quickly as possible. The author, hence, supports the hypothesis that sport staking could improve the same abilities, above mentioned, that it requires and accordingly these skills could be transferred into the various ADL, into sport/recreational activities and on academic requirement such as handwriting which has been tested in this study too as transfer indicator.

2.4.1 Sport Stacking – an alternative intervention?

Sport stacking is an exciting individual and team sport activity where participants stack and unstack 12 specially designed plastic cups in predetermined sequence and compete for time either against another player or a team. Sequences are usually pyramids of three, six, or ten cups.

Generally named also *cup stacking*, it originated in the early 1980-s in southern California as a recreational activity. Wayne Godinet was the man who invented the first formations and gave the name to the Cup Stack (Karango Cup Stack). Godinet originally used paper cups, although plastic cups have now taken over. The first competition was held in 1985 in southern California and gained national exposure on the “Tonight Show” with Johnny Carson in 1990 when he hosted the first live television appearance of cup stacking demonstration.

The original paper cups were found to be too light and flimsy. The cups of today are made of a strong plastic with a texture gripping on the outside to prevent slipping. They have a smooth inside surface to allow the cups to slide over each other with less friction. The new cups also have holes in the bottom to decrease air resistance.

Later Godinet worked together with Bob Fox, the Speed Stacks Inc. founder. After a tremendous response Speed Stacks, Inc. was born as a small home business designed to promote sport stacking and be a resource to physical education teachers. The sport popularity continues to grow exponentially and is now expanding internationally, gaining attention in countries such as Canada, Japan, Australia, Scandinavia, Singapore, Germany, and the United Kingdom. As of summer-2007 more than 20,000 schools worldwide have a sport stacking program as part of their PE curriculum.

The popularity of sport stacking led to create the World Sport Stacking Association (WSSA), formed in 2001 for the purpose of promoting and governing sport stacking around the world. This association serves as the governing body for sport stacking rules and regulations and provides a uniform framework for sport stacking events; sanctions sport stacking competitions and records.

Since promoters claim that participation in this activity will result in many direct and indirect benefits (Speed Stack Inc., 2001) the sequent section gives us an excursus of studies, conducted so far, about the resulting effects of participating in sport stacking in order to give rationale to the benefits hypostasized.

Benefits

Udermann and colleagues (Udermann et al., 2004), within one of the most significant study about sport stacking, showed a significant increase in both hand-eye coordination and reaction time in a group of second grade individuals that received training in cup stacking and measured, before and after the whole training, by the Soda Pop and Yardstick tests (Hoeger & Hoeger, 2004).

The study was held in a public elementary school located in the central western part of the USA. Forty-two second grade students from two different physical education classes participated. The intact classes were randomly assigned as either the treatment (n=21) or the control group (n=21). The former completed 20/30 min. sport stacking session (approximately 4 per week) which were incorporated into their physical education class over 5 weeks. The latter participated in regular PE classes over the same period of 5 weeks.

The results of such study indicated that sport stacking positively influenced scores on tests to measure hand-eye coordination and RT in those second-grade students.

The influence on hand-eye coordination has also been investigated on 103 first-, third-, and fourth-grade students (Hart et al., 2004). The students participated in a three-week sport stacking unit and were measured in three different aspects of hand-eye coordination. The total time spent stacking in this study was five hours. Since significant changes were found in only one of the three hand-eye coordination measurer, the researchers suggested stacking for a total of five hours during a three week unit plan may not be long enough to elicit psychomotor changes.

The results of a Gibson and colleague paper presented at 2007 AAHPERD (American Alliance for Health, Physical Education, Recreation, and Dance) national conference in Baltimore ("Distribution of practice on cup stacking performance") agreed with the claims that practicing cup stacking can improve reaction time (RT) (Gibson at al, 2007).
The purpose of this study was to test two separate techniques of practice on sport stacking performance. Thirty volunteer participants ranging between 19-27 years old, all of whom had no prior training or experience in cup stacking, were randomly assigned to the massed (n=10), distributed (n=10), and control (n=10) practice sessions. The massed group practiced a series of stacking sequences for 60 consecutive minutes. The distributed group, practiced for three 20-minute sessions. Sport stacking performance between these two groups was compared by examination of stacking time for three sequences (6; 3-6-3 and 6-6) with the latter sequence serving as a transfer test. The control group did not practice cup-stacking. All groups were pre-

and post-tested on RT, using the same Yardstick test as reported by Udermann, and colleague (Udermann et al., 2004). It was concluded that practicing sport stacking in a distributed fashion will lead to better performance (see figure 3) and that even 60 minutes of cup stacking practice can improve RT in young adults.

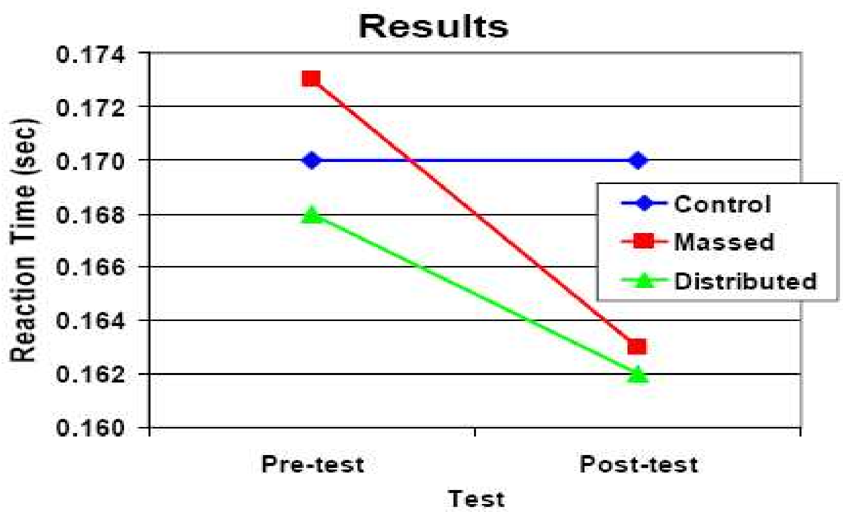

Figure 3. Reaction time means for each groups before and after sport stacking practice (Gibson at al, 2007).

Liggin and colleagues can confirm the above study, asserting that in their research the experimental group participating in a sport stacking exercise program had a significant improvement RT, however, this was not the case for the control group with no such an intervention (Liggins et al., 2007).

Their study attempted, indeed, to examine the effects of a 12-week sport stacking exercise intervention on motor development for elementary school children. Specifically, influences of the sport stacking activities were assessed by measuring the changes of selected psychomotor performances between control and experimental groups. Eighty second graders were randomly selected (M age = 7.1 years, SD = .36). Thirty-six students participated in a cup-stacking exercise program for 15 min every day for 12 weeks and 44 students served as the control with no such an intervention. Three psychomotor performance tests were selected to measure the speed of information processing, upper-limb fine motor control and eye-hand coordination: (a) Finger Choice Reaction Time (RT); (b) Manual Dexterity Test; (c) Rotary Pursuit Tracking Task. These tests were administered at the beginning and the end of the 12-week program for all the participants. They concluded that sport stacking exercise is effective in two-choice RT among the children whom completed the training; moreover they claimed that such an activity is easy to set up at any school settings and children love to learn and practice it.

Conn (2004) used cup stacking as means to change reaction time and movement time in both the dominant and non-dominant hands. She studied 82 fourth-grade students from four different physical education classes in her study. All of the students were pre and post-tested for reaction time and movement time of both hands. The classes were divided into two groups, a treatment group and control group. The treatment group participated in a five-week cup stacking unit that used random practice rather than blocked practice with cups from Speed Stacks, Inc. This means that the cup stacking activities were randomly practiced with scooter activities and volleyball activities. The control group received no instruction in cup stacking. They participated in flag football, scooters, and volleyball units during the research project. During the pre-test, the researcher found no significant differences for reaction time and movement time between both of the groups. In the post-test for the treatment group, the researcher found differences in movement time for both groups, but no significance in reaction time for either group.

A research conducted by Hart and Bixby (2005) deals with the activation of both brain hemispheres during sport stacking. They report that by empirically examining the electrical activity of the two hemispheres of the brain sport stacking participants, during cup stacking activities, use both sides of their bodies and brains to develop skills and to learning.

The purpose of this study was to empirically examine the electrical activity of the two hemispheres of the brain, as measured by electroencephalogram (EEG), while cup stacking. Participants (N=18) were college-age volunteers who completed two practice sessions (30 minutes each) and one testing session. For the testing session, the participants were fitted with the EEG electrode cap following the standard electrode placement of the International 10-20 system. The participants then completed five baseline trials (30 seconds each) in which they were asked to stand quietly looking at the cups. Following the baseline, the participants performed five trials for each of four tasks learned during the two practice sections (i.e., the cycle stack using both hands, the cycle stack using only the right hand, the cycle stack using only the left hand, and the cycle stack using both hands with the Mini *Speed Stacks*). The results of this study support the claim that cup stacking does utilize both sides of the brain. Moreover, those who participate in sport stacking, in order to play correctly, needs to cross the midline. The latter is such an activity that, by making new connections at a brain level and allowing right and left hemispheres to work together, gives several important benefits in the cognition domain (e.g. improvements in concentration, problem solving, and general learning) (Madigan, 2000).

Rhea (2004) assessed the influence of a 5 week sport stacking intervention on upper limb coordination. The specific aims of this study were to measure upper limb coordination changes with a star tracer task and two subtests of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) (Bruininks, 1978) as well as to three dimensionally analyze the sport of cup stacking. The participants (N=26) for this study were students from a middle school in the south-eastern United States. Their age ranged from 11 to 12 years old. They were placed randomly into two groups. One group served as the control group and did not receive any more instruction or practice time with cup stacking. The second group served as the cup stacking (experimental) group. They received cup stacking practice and instruction everyday of their physical education class, which is every other day. At the beginning of every physical education class during this experiment, the cup stacking group received cup stacking instruction for the first 15 minutes of class. The only difference between the two groups was that the cup stacking group received cup stacking instruction while the control group did fitness activities. The cup stacking lessons were adapted from the instructional lessons that Speed

Stacks, Inc. provides with the school pack. As a result, Rhea found that cup stacking has a positive effect on the development of bilateral coordination in sixth grade physical education students.

Murray and colleagues, from their research study called “Energy Expenditure of Sport Stacking”, assessed the energy expenditure of sport stacking (Murray et al., 2007).

Table 3. Stack performed and energy expenditure while standing and sport stacking (Murray et al., 2007).

Stack Performed Sport Staking		Energy Expenditure Standing		Energy expenditure
METs		ml/kg/min	METs	ml/kg/min
Youth 3.1 ± 0.5	31.2 ± 6.5	6.3 ± 1.1	1.8 ± 0.3	8.4 ± 0.3
Adult 2.6 ± 0.7	31.5 ± 4.4	4.9 ± 1.5	1.4 ± 0.4	7.0 ± 0.4
Male 3.1 ± 0.5	29.9 ± 6.3	6.1 ± 1.2	1.7 ± 0.3	10.7 ± 1.8
Female 2.7 ± 0.7	33.6 ± 4.6	5.5 ± 1.6	1.6 ± 0.4	9.5 ± 2.4
Overall 2.9 ± 0.6	31.4 ± 5.9	5.9 ± 1.4	1.7 ± 0.4	10.2 ± 2.2

Thirty-seven subjects (25 youths, mean age = 11 + 1.6 years, 17boys, 8 girls; 12 adults, mean age 25.3 + 3.8 years, 5 men, 7 women) participated in this study. Subjects reported to the laboratory, were informed of the procedures, signed consent forms, and height and weight were obtained. Expired respiratory gases (AEI Technologies) and heart rate (Polar monitors) were measured for 10 min. For the first 5 min, subjects stood stationary for baseline readings to be measured. Next, subjects sport stacked for 5 min, performing as many 3-6-3 stacks as possible. The number of stacks completed was recorded.

It was found out that sport stacking has an energy expenditure of 3.1 METs (see table 3), therefore can be classified as a moderate-intensity activity, and it is similar to other activities involved in typical physical education courses (e.g. weight lifting light to moderate, archery, bowling, volleyball, dance, walking 2.5 mph), meeting the National Association for Sport and Physical Education (NASPE) standards (Sutherland, 2006).

3 Methods

3.1 Participants

In this study 20 children (11 boys, 9 girls) aged 7 to 11 (mean = 9.20, sd = 0.97 years) started the intervention. However, only 15 of them (7 boys, 8 girls) aged 8 to 11 (mean = 9.09, sd = 0.87 years) finished the intervention phase and concluded at least the 83% of the whole program. The dropout-group shows no significant differences for the examined variables compared to the intervention group.

The children, attending the 3rd, 4th , 5th and 6th school grades, were recruited from two different primary schools in the Merseyside area of Liverpool.

3.2 Instrumentation

In this research the school pack from Speed Stacks Inc. was used as a training instrument, while the materials for carrying out the tests and reported below in details were the second edition of Movement Assessment Battery for Children (MABC-2), the Detailed Assessment of Speed of Handwriting test (DASH), the Children's Self Perceptions of Adequacy in and Predilection for Physical Activity (CSAPPA), and a special mat for the stack test (i.e. the modified Soda Pop test).

Sport Stacking Equipment

The school pack from Speed Stacks Inc. consists of 30 sets of cups made specially for cup stacking. Each set includes 12 cups. The school pack also includes a reaction timer for competition, a set of mini cups, and a set of weighted cups. Lesson plans that accompany the school pack and other printed cup stacking resources were employed for this study.

The Movement Assessment Battery for Children, second edition (MABC-2)

The Movement Assessment Battery for Children (MABC-2) (Henderson, Sugden, & Barnett, 2007) is a global test of motor proficiency, assessing both gross and fine motor coordination in children aged from 3 to 16 years.
It is the most frequently used standardized motor test to screen for identification of children with DCD in research (Wilson, 2005) and is well-known for a high standard of reliability and validity (Crawford, Wilson, & Dewey, 2001; Miyahara et al., 1998; Tan, Parker, & Larkin, 2001; Chow & Henderson, 2003; Bom Fiers et al., 2007). Moreover, although some of the change made to the second edition test might be regarded as substantial (e.g. the extension of the age range), the item content is considered to be sufficiently similar for the studies that have employed MABC to remain relevant (Barnet & Henderson, 1998; Geuze et al, 2001).
The MABC is administered in a one-to-one testing situation by trained Physical Education teachers according to the procedures outlined in the MABC manual. The test is divided in three age bands, such as AB1: 3 to 6 years; AB2: 7 to 10 years; AB3: 11 to 16 years. Within each age band, eight items are grouped under three headings: 3 Manual Dexterity items, 2 Aiming and Catching items pertaining to ball catching proficiency, and 3 Bal-

ance items pertaining to both static and dynamic balance (see figure 4). The items are scored between 0 (no impairment) and 5 (severe impairment). The total impairment score of the test is the sum of the scaled scores with a maximum of 40. For the free components of the test (manual dexterity, aiming and catching and balance) and for the total score, age-adjusted standard score and percentile are provided. Scores less than or equal to the 5th percentile indicate definite motor problems, scores between the 6th and the 15th percentile indicate borderline motor problems (Geuze, Jongmans, Schoemaker, & Smits-Engelsman, 2001).

Figure 4. MABC-2, "one-board balance" item, AB2 (7-10 years).

Detailed Assessment of Speed of Handwriting (DASH)

It is a useful tool in identifying children with handwriting difficulties and in providing relevant information for planning intervention (Barnett, Henderson, Scheib & Schulz, 2007). The assessment includes five subtests, each testing a different aspect of handwriting speed. The subtests examine fine motor and precision skills, the speed of producing well known symbolic material, the ability to alter speed of performance on two tasks with identical content and free writing competency. Two tasks, “copy best” and “copy fast”, involve copying the same sentence – first, in the student’s best handwriting for two minutes (see figure 5), then as quickly as possible (see figure 6), but legibly, for the same length of time. The rationale for including two tasks with identical content and identical time constraints is to provide a directly comparable contrast in speed of performance. Between the two copying tasks, the DASH “alphabet writing” item requires children to write the alphabet in lower case continuously for one minute. As Connely and colleagues (2006) state, this is a very well-researched task that offers an insight into how fast the child can generate material that is over-learned in most cases. Furthermore, this item has proved to be a good predictor of both compositional fluency and quality (Graham et al,. 1997). The forth task is a free writing task and was not included in this research because its meaning is not related to writing velocity. Finally, the DASH contains an optional task: the “graphic speed“, which requires the child to make a series of crosses within circles, focusing more on the fine motor/precision aspects of making a mark. The rationale for including this test is to represents a “purer” measure of perceptual-motor competence.

Taken as a whole, this set of tasks covers a fairy broad range of the component skills involved in the process of handwriting. As scores of four of the five tasks are very correlated, they can be summed and converted into a total standard score, which can be viewed as a global measurer of handwriting speed.

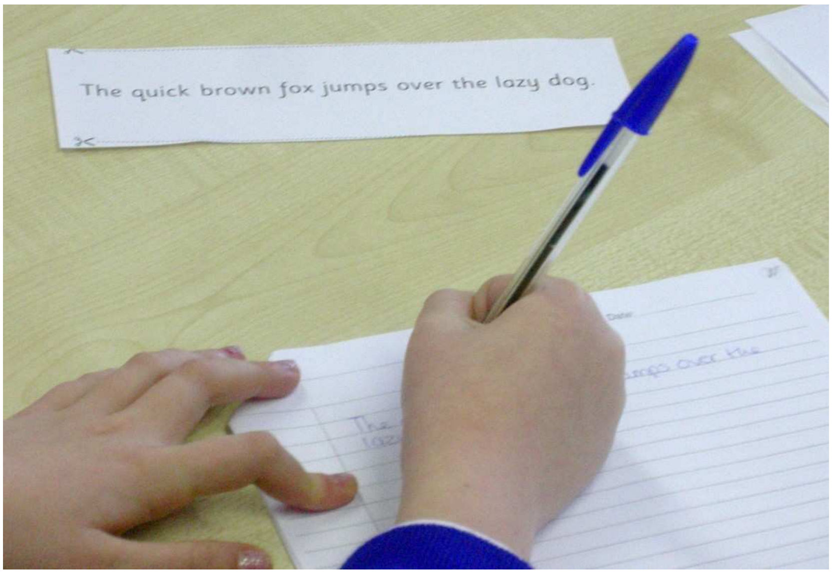

Figure 5. DASH test, “copy best” item.

Figure 6. DASH test, “copy fast” item.

Generalized Self-Efficacy Toward Physical Activity (CSAPPA)

The Children’s Self Perceptions of Adequacy in and Predilection for Physical Activity (CSAPPA) (see appendix 1) scale is a 20-item scale designed to measure children’s self-perceptions of their adequacy in performing, and their desire to participate in, physical activities (Hay, 1992). This self-report scale requires approximately 20 minutes to complete, and uses a structured alternative choice format to present descriptions of physical activities. For example, a child is asked to choose which one of a number of pairs of sentences describes him/her most such as “some kids are among the last to be chosen for active games” but “other kids are usually picked to play first” and then to indicate whether the selected sentence was “sort of true for me” or “really true for me”.

Hay designed the CSAPPA scale for children aged 9 to 16 years, and it has demonstrated a high test-retest reliability (r = .84-.90), as well as strong predictive and construct validity (Hay et al, 2004; Wrotniak et al., 2006).

This tool has 3 imbedded factors: adequacy (confidence in), predilection (preference for), and enjoyment of physical education class. The scale in total measures generalized self-efficacy toward physical activity.

In this study, we used each of these 3 subscales, such as adequacy, enjoyment and predilection, to assess different dimensions of generalized self-efficacy toward PA.

Modified Soda-Pop test (stack test).

The original Soda Pop test is a documented test of eye-hand coordination (Hoeger & Hoeger, 2004). The test involves constructing a cardboard platform 32 in. (81.28 cm) high and 5 in. (12.7 cm) wide. Six circles, 3.25 in. (8.26 cm) in diameter, are drawn centred on the cardboard 1.5 in. (3.81 cm) apart. Three full soda pop cans are used for the test and are placed in every other circle starting from the side of the hand being tested. The author adapted the test by using Speed Stacks cups rather than cans and a stacking mat with six circles drawn on it rather than the platform. So that three stacking cups are placed in every other circle starting from the side of the hand being tested, see figure 7. The participant begins the test by putting his/her hands on the sensors of the timer. The task is to turn each cup upside down in the adjacent empty circle within the drawn line. The participant then returns to the first cup turned, replaces it in the original position and proceeds with the other two cups. The whole process is repeated twice. Each child completed 4 trials in total, two starting with the left hand and two starting with the right hand. The participant was given a practice trial.

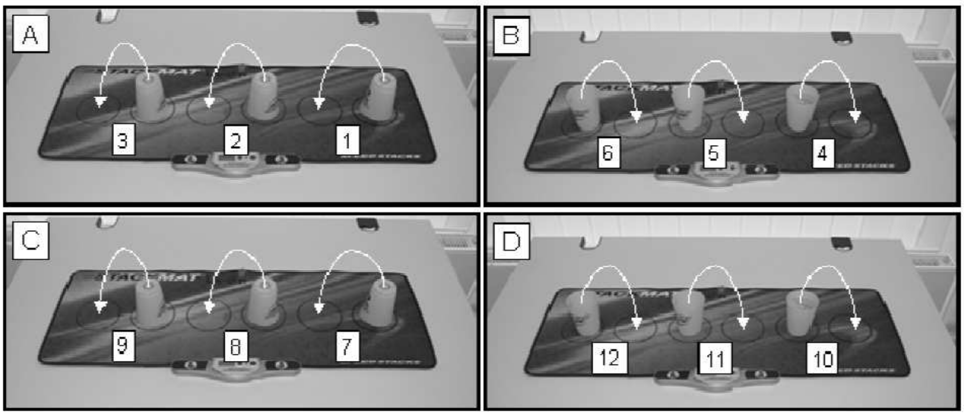

Figure 7. Adapted SODA POP test.

3-3-3 test

The 3-3-3 test is the simplest sport stacking competition (Sport Stacks Inc.). Starting with three nested stacks of 3 cups, it consists of creating three pyramids of 3 cups each, working from left to right or vice versa, and then going to the beginning to downstack the cups, in the same order of the up-stacking phase into nested stacks of 3.

Stackers should complete one stack at a time to follow the rules. They must also fix the fumbles in the same time they occur (a fumble is when a cup falls off, slides down, tips over, or is not stacked on the top surface of a cup). The only exception to fixing fumbles is during the downstacking phase: if all stacks are up and the stacker accidentally knocks a stack over, he can fix it whenever he wants.

3.3 Procedures / Intervention

The cohort of this research was recruited showing a flyer (see appendix 3) about the intervention proposed alongside the hypothesized beneficial effects of participating in sport stacking, the tests involved, and a short presentation on sport stacking.

A part of the 3-3-3 stack test, that was first taught and than employed as a test during the first training section, all the pre-tests were completed during the first week of the program and in a one to one situation. Furthermore, a 3-3-3 stack test was employed once a week (i.e. in total of 4 times, pre and post-test included), two trials and one practice were completed per each test.

None of the participants had any prior experience in sport stacking. They were taught separately, 10 children per schools, basically the same program, in either a physical education hall or in a regular classroom.

All of the children (N. 15), who concluded the whole program, received 12 sections of sport stacking training, 45 min. per section, and sorted in 3 sections per week within a 4-week comprehensive intervention. However, the whole training intervention lasted 5 week, because of a week off observed by both schools. Including the first pre-test week and the last post-test week, the whole experiment lasted a total of 7 weeks.

The sport stacking training was composed of a learning phase, in which the first two basic competitions have been taught (the 3-3-3 stack and the 3-6-3 stack), combined with a physically active phase in which the sport stacking sequences were included in fun games, pathways, and both individual and team challenges/relays. Upon the completion of the learning phase (within the first 4 sections), the sections were mainly focused on employing the sport stacking sequences in physically active games in order to get a positive effect not only by sport stacking activity per se, but even by increasing the children's physical fitness level. Nevertheless, a physical activity phase was included in every section, even during the first 4 sections in which the focus was especially on learning the sport stacking sequences.

The following is an example of a sport stacking section used as training: the 4th section in which the 3-3-3 stack was already metabolized by all the children and the further step consisted in introducing the 3-2-1 method, which contains training for further learning of the second sport stacking competition: the 3-6-3 stack.

Sport stacking training - example of a section - section n.4:

1) Warm up 1: the children are seated, together with the instructor, in a circle on the floor, with 2 stacks (i.e. 2 sets) of 3 cups nested together,

the instructor starts the game upstacking (i.e. building) and downstacking (i.e. taking down) the 2 stacks (that is basically a 3-3-3 stack, the easiest sport stacking sequence, without one stack becoming a 3-3 stack), when he finishes he "gives a five" to the child seated on his left that will start the same task and so on with other children. The game is concluded once clockwise and once counter-clockwise. The instructor should emphasize that the task has to be accomplished not only as quickly as possible, but also in a proper way (see figure 8).

Figure 8. Section n. 4; Warm up 1.

2) Warm up 2: this is the same warm up reported above, but upstacking and downstacking not a 3-3 stack but a 3-3-3 stack (i.e. 3 sets of 3 cups).

3) Learning phase (the main part): with all 6 cups nested together, the children are seated on the floor, in front of the instructor that explains

the 3-2-1 method first by showing and then practicing together with the children the necessary tasks to learn this method. The instructor works in front of the children in order to let them look at him/her and work as in front of a mirror. Moreover, the instructor should point out the importance of being really slow in this learning phase in order to be faster afterwards once the task has been internalized and the velocity acquired.

4) Competition: the children are again seated on the floor in a circle with 3 stacks of 3 cups nested together, they practice with the 3-3-3 stack (first sport stacking official competition), then the instructor gives the start cue and they have several collective challenges (see figure 9). The instructor should assist with tips during the practice (e.g. "slide, don't slam", "focus on one stack per time", "use both hands", "fix the fumbles just when they happen", and so on) and remind about the starting and finishing position before the competition: both on the floor close to the centre stack (this is the same position that activates and stops the chronometer while carrying out the 3-3-3 test).

Figure 9. Section n.4; 3-3-3 competition.

5) Game: several 3-3-3 stacks are placed on the floor randomly with a lot of space left between a 3-3-3 stack and between one another; at the start cue of the instructor, each child executes the 3-3-3 stack (upstack, back to the beginning and downstack) of the closest to him/her stack and upon conclusion, he runs to find a free 3-3-3 stack in order to upstack and downstack it. Another rule of this game is to conclude as many 3-3-3 stacks as possible keeping in mind the number of 3-3-3 stacks completed, in order to compete against the other children. The instructor stops the competition after 2 minutes and the child who has completed most 3-3-3 stacks is the winner. This game can be repeated more times and be employed in other sections not only to compete against other children, but also to improve the individual number of 3-3-3 stacks completed.

To conclude the last section, the children were required to build a huge tower with all the cups (see figure 10).

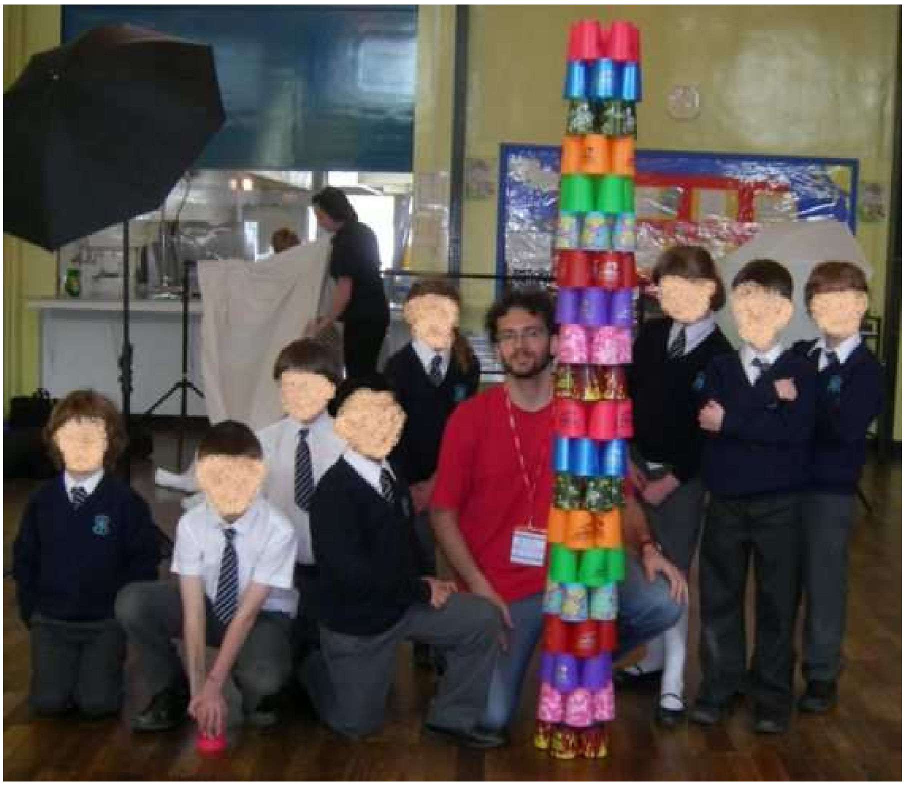

Figure 10. Section n12; Cups tower.

3.4 Data analysis

The data obtained from the MABC-2, the DASH and the CSAPPA were converted from raw score to standard score.

The "Paired samples T test" and the "ANOVA (analysis of variance) with repeated measures" were employed.

The paired samples T test, employed for the MABC, compares the means of two variables. It computes the difference between the two variables for each case, and tests to see if the average difference is significantly different from zero. In this study the variables compared are the results of the pre-test and the results of the post-test.

The ANOVA with repeated measures, similarly to a paired t-test, allows to examine the means for two groups that are related to each other. Moreover, in this kind of analysis the effects of interest are between-subject effects (such as the GROUPS), within-subject effects (such as the TIMES), and interactions between the two types of effects. This analysis allowed us to estimate the difference between pre- and post-tests and difference between children with and without DCD.

The significance value (p value) for all statistical tests was set as “tendency” (T) if $p < 0.10$; as “significant” (*) if $p < 0.05$, and as “highly significant” (**) if $p < 0.01$.

4 Results

MABC-2

Among 15 children who completed the post-test, according to the MABC-2 total scores, five of them were classified as having DCD in the pre-test (i.e. total score below 57, that means at or below the 5th percentile range); however only one of them was classified as being "at risk" for DCD following the post-test (i.e. total score between 57 and 67 inclusive, that means between the 5th and the 15th percentile inclusive).

Table 4 shows that although in the manual dexterity subtest there was an improvement, it was not significant (p= .497). Regarding to aiming & catching and balance, alongside with the total score, there were significant improvements after the training (respectively p= .001; p=.043; p=.004).

Table 4. Mean (M) and standard deviations (SD) for the MABC scores for the 15 children before and after the cup stacking intervention. Results of a paired samples t-test.

	T1		T2		Stat. Analysis	
	mean	sd	mean	sd	t(14)	p
Manual Dexterity	24.13	6.77	25.30	6.41	-0.70	.497
Aiming & Catching	15.53	5.04	19.70	4.80	-4,19	.001
Balance	29.30	7.01	31.70	4.53	-2.22	.043
Total	68.97	14.75	76.70	12.75	-3.47	.004

CSAPPA

As showed in table 5 about the CSAPPA test, although at a descriptive level the total main score obtained would suggest that, after the training, the generalized self-efficacy toward physical activity slightly increased among children without DCD and decreased among DCD children, it can be asserted that there is no statistically significant differences between both groups (p=2.25).

Table 5. Mean (M) and standard deviations (SD) for the CSAPPA scores for the children with (n=5) and without DCD (n=10) before and after the cup stacking intervention. Results of an analysis of variance with repeated measures (^{T} $p<.10$; $*p<.05$; $**p<.01$).

		T1		T2		Stat. Analysis	
		mean	sd	mean	sd	$F_{time}(1,13)$	$F_{timexDCD}(1,13)$
Adequacy	Non-DCD	20.70	5.66	20.20	6.71	1.83	0.41
	DCD	22.00	4.36	20.60	3.58		
Enjoyment	Non-DCD	8.30	2.58	9.60	2.72	0.28	10.71** $\eta^2 = .452$
	DCD	10.00	2.12	8.20	3.90		
Predilection	Non-DCD	28.30	5.66	27.80	7.28	0.15	0.02
	DCD	27.40	5.90	27.00	4.95		
Total	Non-DCD	57.30	12.39	57.60	14.10	1.55	2.25
	DCD	59.40	9.84	55.80	7.46		

The only highly significant result regards the interaction between the two different groups enjoyment scores, in which an enjoyment decrease between pre and post-test can be observed in children with DCD, and an enjoyment increase between pre and post-test in children without DCD. No other significant or major effect or interaction between the scores obtained was reported among both groups.

Handwriting

The DASH test raw scores are showed in table 6. The relevant data is the significant increase of the “copy best” task scores among both groups of children with and without DCD after the training. Moreover, in relation to the “graphic speed” task, in both groups of children, there is a tending improvement achieved after the training.

Although at a descriptive level all the children improved their mean score for each DASH task, yet the underlying result is that no significant interaction was found with regard to the improvement obtained by children groups, both with and without DCD.

Figure 11 reports the DASH test mean standard scores, comparing pre and post-tests of each group (children with and without DCD) for each task.

As already noted in table 6, although every child improved the handwriting velocity after the training for each DASH trial, the only highly significant result pertained to the improvement after the training for the copy best task, achieved by both groups of children. It can be also noted that there is a tendency with regard to the graphic speed task score showed solely among children without DCD.

Table 6. Mean (M) and standard deviation (SD) for the DASH raw scores among children with (n=5) and without DCD (n=10), before and after the cup stacking intervention. Results of a analysis of variance with repeated measures (^{T} p<.10; *p<.05; **p<.01).

		T1		T2		Stat. Analysis	
		mean	sd	mean	sd	F_{time} (1,13)	$F_{timexDCD}$ (1,13)
Copy best	Non-DCD	18.30	6.60	24.20	6.36	26.52** η^2 = .671	0.02
	DCD	13.60	5.68	19.40	6.07		
Alphabet writing	Non-DCD	42.70	15.37	47.80	17.17	0.48	0.09
	DCD	39.00	26.43	41.00	12.90		
Copy fast	Non-DCD	32.40	8.37	36.50	14.55	2.65	0.01
	DCD	24.00	10.79	28.60	10.64		
Graphic speed	Non-DCD	24.40	10.45	29.30	9.17	3.74^T η^2 = .224	0.17
	DCD	18.20	8.84	21.40	5.46		

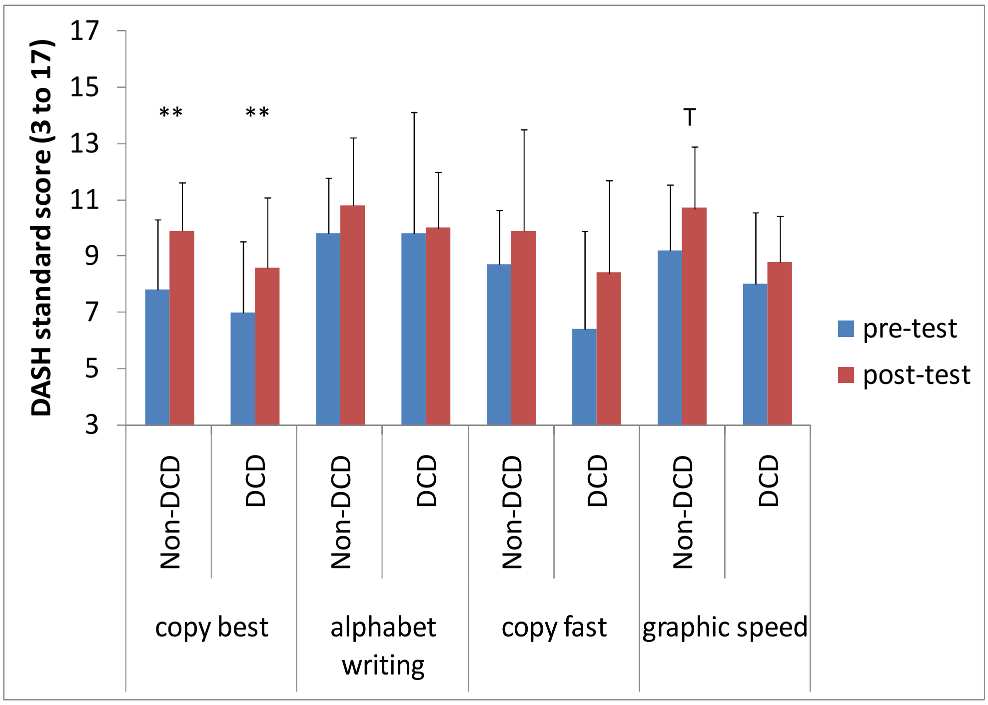

Figure 11. Mean standard scores and standard deviation for each of the DASH tasks for children with and without DCD (^{T} p<.10; *p<.05; **p<.01).

Soda Pop test

The adapted Soda Pop test results are shown in table 9. According to the ANOVA with repeated measures data analysis, it can be noted that there is an highly significant general decrease of mean times between pre and post-test, using both right and left hand, and among both groups of children with and without DCD. Moreover, there is a tendency for interaction within the results obtained by both groups pertaining to solely the right hand task.

Table 9. Mean (M) and standard deviation (SD) for the modified Soda-Pop test for the children with (n=5) and without DCD (n=10) before and after the cup stacking intervention. Results of a analysis of variance with repeated measures (^{T} p<.10; *p<.05; **p<.01).

		T1		T2		Stat. Analysis	
		mean	sd	mean	sd	$F_{time}(1,13)$	$F_{timexDCD}(1,13)$
Stack-Test left	Non-DCD	1974	346	1409	137	29.55** η^2 = .694	0.27
	DCD	2441	958	1757	426		
Stack-Test right	Non-DCD	1609	293	1264	119	15.63** η^2 = .546	3.28^{T} η^2 = .201
	DCD	2528	1457	1600	487		

3:3:3 stack test

The results about the 3-3-3 stack show, as reported in figure 12, that the main improvement between pre and post-test, achieved by both groups of children with and without DCD, was significant for the first three trials and highly significant for the last trial [$F(1,13) = 28.0$, $p < .001$, $\eta^2 = .683$].

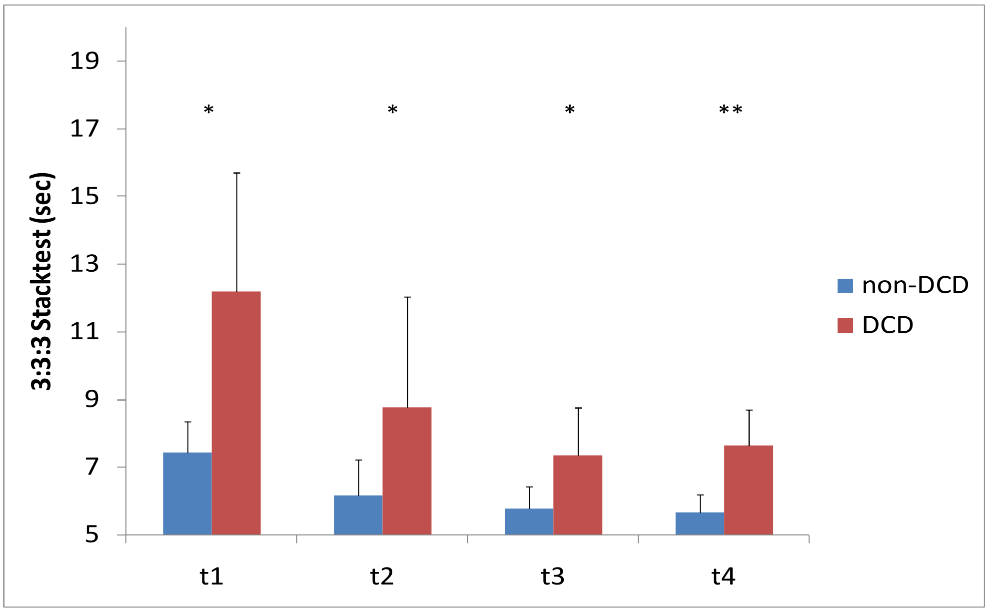

Figure 12. 3-3-3 stack test.

Moreover, there is a significant interaction between the high post-training improvement observed in children with DCD and a slight post-training improvement observed among children without DCD [$F(1,13) = 6.12$, $p = .009$, $\eta^2 = .320$].

5 Discussion and conclusion

The main aim of this study was to determine the effect of a short period (four weeks of training sessions, 130 minutes per week) of sport stacking training, quite recent recreational activity combined with physical activity, on primary school children with and without poor motor coordination. Moreover, the second hypothesis was that any improvement in either hand-eye coordination or general motor coordination positively affects the generalized self efficacy toward physical activity and handwriting.

The modified Soda Pop test results indicate that children's hand-eye coordination improved significantly after the training period. Moreover, as the MABC-2 total scores show, children's general motor coordination improved significantly in the way that only one out of five children suffering from DCD, as the same assessment tool suggested, remained in the same poor motor coordination condition after the training. Nevertheless the handwriting test results (DASH) indicate a significant improvement only when the task required children to write in their best handwriting, handwriting velocity increased after the training.

Therefore, the overall improvements achieved by the children assessed let the author claims that even a short period of proposed training, i.e. sport stacking combined with physically active games, affected not only children's hand-eye coordination and several related fine motor coordination skills, such as handwriting velocity, but also their general motor coordination. Nevertheless, according to the CSAPPA scale, there were no significant results pertaining to children's generalized self-efficacy toward physical activity.

The present findings, as reported by the modified Soda Pop test results, support those of the studies conducted by Udermann and colleagues (Udermann et al., 2004) and by Hart and colleagues (Hart et al., 2004) who also found that sport stacking training can significantly increase hand-eye coordination proficiency. Moreover, as shown in table 9, the same results suggest that the gap between right and left hand after the training is quite minor as compared to he gap before the training, which means improvement in bilateral coordination. This last finding supports the Rhea study (2004) in which it was concluded that sport stacking training has a positive effect on the development of bilateral coordination and ambidexterity.

Although the results reported in table 4 show that the training affected considerably both aiming & catching and balance proficiency, the effect was minor for children's manual dexterity, these findings are supported and explained by already mentioned dynamical system theories. Indeed, obtained improvement within a specific area, i.e. manual dexterity, is closely linked to sport stacking activities, and according to the dynamical system approach, every area is considered a possible constraint on the whole motor coordination system; therefore this improvement can affect a faster development of other skills, apparently slightly linked to the proposed training, thus consequently affecting the whole system. This way, even a minimum improvement in a specific area (i.e. manual dexterity) can lead to achievement of a critical level, specific for each individual, that can hugely affect the whole system and/or other specific domain not closely related to manual dexterity, such as the balance and aiming & catching.

The small sample size, lack of a control group, relatively short period of the training and lack of validation of the modified Soda Pop test are all limits on the current study; moreover the identification of DCD children via the MABC, although this is the most commonly employed DCD screening tool, should be at least combined with a questionnaire to exclude important medical conditions, especially neurological, that could be the real cause of the children's poor motor coordination. Nevertheless this was the first and hence a pilot study of assessment of the effect of sport stacking on children with poor motor coordination, besides, the awareness of these limits is of help to develop further studies that the author himself wishes to conduct in the future to validate the current encouraging results.

Furthermore, the ecological perspective alongside with the Newel's model (1985), claiming that movements arise from the interaction of more then one factors, such as individual, environment and task, suggests that the findings obtained are the result of a lot of variables that can affect the final results. Even the causal modelling (Morton 2004, Morton & Frith, 1995) highlights the importance of taking into account the environment factor which can affect every step of the causal chain pertaining to biological and cognitive factors/constraints to justify a relatively observable behaviour.

Accordingly, further studies could explore these aspects to find a scientific way of measuring as many constraints as possible within the experiments in order to make sure that a score resulting from a research is the mirror of not only the treatment employed, but also of all the factors that can influence the final raw score.

Therefore the author suggests the following: to repeat the same study taking into account several aspects that were not considered in the current research:

- different results obtained between boys and girls and between right handed and left handed children
- part of the school curricular schedule in which sport stacking training is included (extra scholastic activity, scholastic activity, lunch time, other breaks, etc)
- time of the day when sport stacking training is carried out
- socio-economical aspect of the children's family
- children's psychological well-being
- parents/relatives' awareness of the eventual children's motor coordination disorder
- time of the day when the tests are carried out

Of course both the heterogeneity of DCD and quite recent idea of sport stacking as a possible treatment to improve motor coordination disorders, makes this kind of research not so easy to conduct; it is also time consuming and expensive from an economical point of view; on the other hand the results of the few conducted studies are really promising.

Finally, the present findings give rise to the hypothesis that sport stacking can be referred to as a process oriented approach in which hand-eye coordination is the fundamental skill to be treated to reach the development of other skills related to motor control, with the final goal of transferring the general motor coordination improvements to the activities of daily living (ADL), academic and sport achievements and, as a result, to a better psychosocial well-being.

The author, hence, concludes that sport stacking not only could be adopted by physical education (PE) programs, but also included in a more comprehensive treatment of such motor coordination disorders as DCD. Indeed the benefits associated with and attributed to this activity, lead to improvement of children with DCD as well as in typically developing children. So that, even though further researches are required to validate and give rationale to the few encouraging results, there are good possibilities that sport stacking can become fundamental for typically developing children to reach a faster motor control development and for children with DCD to get sufficient motor control levels. Moreover, since DCD is often underestimated and the referral age is from about 6 to 8 (Gibbs et al., 2007), the use of this activity by primary schools might be of great help especially for those children that are not easily identified as suffering from the disorder giving them the possibility to improve their poor motor coordination, otherwise hard to outgrow.

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7 Appendices

APPENDIX 1: CSAPPA

WHAT'S MOST LIKE ME!

Name: ____________________ **Birthday**:____ /____ /____ **Age**: ____ years

Month/Day/Year

Grade: _________ **I am a**: ❒ **Boy / ❒ Girl**

INSTRUCTIONS: Remember this is not a test –there are no right or wrong answers – only you know the best answers! In this survey you have to read a pair of sentences and then circle the sentence that you think is more like you.

Once you have circled the sentence that is more like you, then you have to decide if it is REALLY TRUE for you or SORT OF TRUE for you.

Here is a sample question for you to try. Remember; first circle the sentence that is more like you and then put a check (✓) in the correct box if it is **really true** or only **sort of true** for you. There are no right or wrong answers, just what is ***MOST LIKE YOU***!

REALLY TRUE for me	**SORT OF TRUE for me**				**SORT OF TRUE for me**	**REALLY TRUE for me**
❒	❒	Some kids like to play with computers.	**BUT**	Other kids don't like playing with computers.	❒	❒

Now you are ready to start filling in this form. Take your time and do the whole form carefully. If you have any questions just ask! If you think you are ready you can start now. BE SURE TO FILL IN BOTH SIDES OF EACH PAGE!

REALLY TRUE for me	SORT OF TRUE for me				SORT OF TRUE for me	REALLY TRUE for me
❒	❒	Some kids can't wait to play active games after school.	BUT	Other kids would rather do something else.	❒	❒
❒	❒	Some kids really enjoy physical education class.	BUT	Other kids don't like physical education class.	❒	❒
❒	❒	Some kids don't like playing active games.	BUT	Other kids really like playing active games.	❒	❒
❒	❒	Some kids don't have much fun playing sports.	BUT	Other kids have a good time playing sports.	❒	❒
❒	❒	Some kids think physical education is the best class.	BUT	Other kids think physical education isn't much fun.	❒	❒
❒	❒	Some kids are good at active games.	BUT	Other kids find active games hard to play.	❒	❒
❒	❒	Some kids don't like playing sports.	BUT	Other kids really enjoy playing sports.	❒	❒
❒	❒	Some kids always hurt themselves when they play sports.	BUT	Other kids never hurt themselves playing sports.	❒	❒
❒	❒	Some kids like to play active games outside.	BUT	Other kids would rather read or play video games.	❒	❒
❒	❒	Some kids do well in most sports.	BUT	Other kids feel they aren't very good at	❒	❒

REALLY TRUE for me	SORT OF TRUE for me				SORT OF TRUE for me	REALLY TRUE for me
				sports.		
❒	❒	Some kids learn to play active games easily.	BUT	Other kids find it hard learning to play active games.	❒	❒
❒	❒	Some kids think they are the best at sports.	BUT	Other kids think they aren't very good at sports.	❒	❒
❒	❒	Some kids find games in physi-cal education hard to play.	BUT	Other kids are good in games in physical education.	❒	❒
❒	❒	Some kids like to watch games being played outside.	BUT	Other kids would rather play active games outside.	❒	❒
❒	❒	Some kids are among the last to be chosen for active games.	BUT	Other kids are usually picked to play first.	❒	❒
❒	❒	Some kids like to take it easy during recess.	BUT	Other kids would rather play active games.	❒	❒
❒	❒	Some kids have fun in physical education class.	BUT	Other kids would rather miss physical education class.	❒	❒
❒	❒	Some kids aren't good enough for sport teams.	BUT	Other kids do well on sport teams.	❒	❒
❒	❒	Some kids like to read or play quiet games.	BUT	Other kids like to play active games.	❒	❒

REALLY TRUE for me	**SORT OF TRUE for me**				**SORT OF TRUE for me**	**REALLY TRUE for me**
❐	❐	Some kids like to play active games outside on weekends.	**BUT**	Other kids like to relax and watch TV on weekends.	❐	❐

PLEASE CHECK TO MAKE SURE THAT YOU HAVE ANSWERED ALL THE QUES-

TIONS!

THANK YOU!!!

APPENDIX 2: Intervention flyer

Influence of cup stacking on motor coordination and self-efficacy

Prof. Dr. Nadja Schott, Dr. Ilka Seidel, Luca Aparo

The significance of examining the gross motor performance of children with poor motor coordination lies in the underlying importance of these skills in the life of a child. It has been recognized that adequate performance in early gross motor skills is of paramount importance in learning more complex activities. Without these prerequisite skills, children may experience difficulties in school, playground, and other activities of daily living. Competence in gross motor skills contributes to a child's level of fitness. Poor physical health due to inadequate motor performance may in turn lower the desire to be physically active. Further, lack of participation in the playground activities may have a negative impact on a child's self concept leading to various emotional and behavioural problems. Athletic competence and physical appearance have also been determined to be one of the most important social status determinants. Thus, understanding and identifying the gross motor deficits associated with poor motor coordination may assist physical educators and practitioners in providing appropriate movement education for these children, with programs specifically designed to improve the gross motor skills that are problematic for the child. Such interventions will help not only to improve the quality of present life for the child, but also prevent associated behavioural problems.
Recently Cup Stacking was introduced as an activity in schools. Cup Stacking is an individual or team activity where participants stack and un-stack specially designed plastic cups in pre-determined sequences while racing against the clock for the fastest time. Speed Stacks Inc. claims that cup stacking promotes and increases hand-eye coordination, quickness, reaction time and ambidexterity. Although Speed Stacks, Inc. has made claims that the task will enhance motor skills, there is limited empirical evidence that can support their case.

Purpose

The purpose of this study is to examine the influence of a cup stacking intervention on motor coordination (especially eye-hand coordination) and self-efficacy.

Method

Participants

A sample of 100 children, aged between 8 and 12 years will be recruited from various schools from the Merseyside area.

Measures

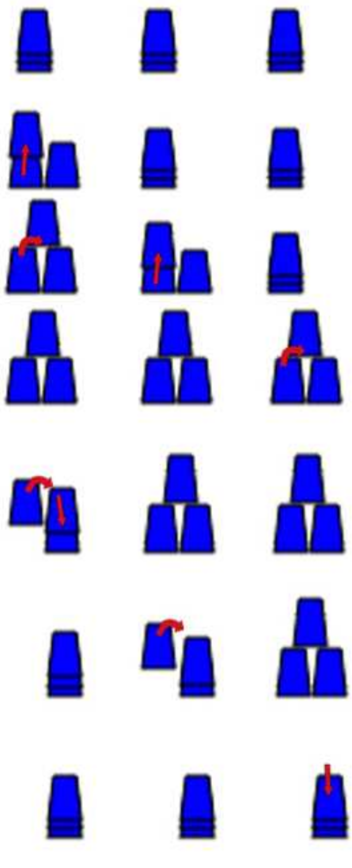
The Movement Assessment Battery for Children. We employ the Movement Assessment Battery for Children (MABC2; Henderson, Sugden, & Barnett, 2007) as a global test of motor competence, assessing both gross and fine motor coordination in children aged 3 to 16 years. It is the most frequently used standardized motor test to screen for identification of children with DCD in research (Wilson, 2005) and is well-known for a high standard of reliability and validity (Crawford, Wilson, & Dewey, 2001; Miyahara et al., 1998; Tan, Parker, & Larkin, 2001). The MABC is administered in a one-to-one testing situation by trained Physical Education teachers according to the procedures outlined in the MABC manual. The MABC consists of eight items, scored between 0 (no impairment) and 5 (severe impairment). The total impairment score of the test is the sum of the scaled scores with a maximum of 40. It is grouped as three sub scores: manual dexterity, ball skills, and static/dynamic balance. Scores less than or equal to the 5th percentile indicate definite motor problems, scores between the 6th and the 15th percentile indicate borderline motor problems (Geuze, Jongmans, Schoemaker, & Smits-Engelsman, 2001).

Generalized Self-Efficacy Toward Physical Activity. The Children's Self Perceptions of Adequacy in and Predilection for Physical Activity (CSAPPA) scale is a 20-item scale designed to measure children's self-perceptions of their adequacy in performing, and their desire to participate in, physical activities (Hay, 1992). Hay designed the CSAPPA scale for children age 9 to 16 years, and it has demonstrated a high test- retest reliability, as well as strong predictive and construct validity. The CSAPPA scale has 3 imbedded factors: adequacy (confidence in), predilection (preference for), and enjoyment of physical education class. In this study, we will use each of these 3 subscales to assess different dimensions of generalized self-efficacy toward PA.

Detailed Assessment of Speed of Handwriting (DASH). It plays a role in identifying children with handwriting difficulties and provides relevant information for planning intervention (Barnett, Henderson, Scheib & Schulz, 2007). The assessment includes five subtests, each testing a different aspect of handwriting speed. The subtests examine fine motor and precision skills, the speed of producing well known symbolic material, the ability to alter speed of performance on two tasks with identical content and free writing competency.

Cup-stacking tests (3-3-3; modified Soda-Pop test).

3-3-3



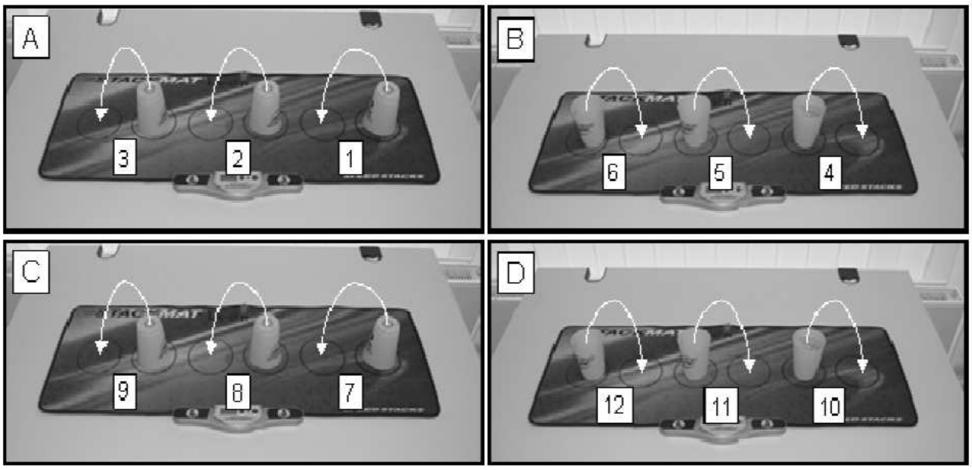
Stackers must begin stacking on the right or left side and work to the other side.

Complete one stack at a time. It might seem faster to stack two at a time, but it's against the rules.

After all stacks are up, go back to the beginning to downstack in the same order. If this rule weren't in place, stackers wouldn't have to correctly stack the third stack. They could keep their hands on the stack and bring it right back down. No one would ever know if that stack would have stayed up. So back to the beginning we go.

You must fix your fumbles as you upstack (a fumble is when a cup falls off, slides down, tips over, or isn't stacked on the top surface of a cup). In a tournament setting, a required fumble fix that is ignored means your attempt is a scratch (no time recorded), even if it's a world record. The one exception to fixing fumbles is when downstacking. If all stacks are up and you accidentally knock any stack over, you can fix it when you want. Just make sure that you end with the same stacks as when you started.

modified Soda-Pop test. The original Soda Pop test is a documented test of eye-hand coordination (Hoeger & Hoeger, 2004). The test involves a stacking mat. Six circles are drawn on the mat. Three Stacking cups are placed in every other circle starting from the side of the hand being tested. The participant begins the test by putting his/her hands on the sensors of the timer. The task is to turn each cup upside down in the adjacent empty circle within the drawn line. The participant then returns to the first can turned, replaces it in the original position and proceeds with the other two cups. The whole process is repeated twice. There will be 4 trials in total, two starting with the left hand and three starting with the right hand. The time of each test will be recorded. The participant is given a practice trial.



Procedures

Participants will be pretested on the Movement Assessment Battery, the Detailed Assessment of Speed of Handwriting, the Generalized Self-Efficacy toward Physical Activity and the cup-stacking tests. Following the pretests the treatment group will be given instructions on the proper stacking techniques. Students will participate in cup-stacking activities for three days per week for a 6-week period. Each class will be 45 minutes. During the training session for cup stacking a number of additional tasks will be incorporated to improve physical fitness. At the conclusion of the six week training period, every participant will be again tested with the Movement Assessment Battery, the Detailed Assessment of Speed of Handwriting, the Generalized Self-Efficacy toward Physical Activity and the cup-stacking tests.